

STANDARDS DEVELOPMENT BRANCH OMOE



3693600000-4363

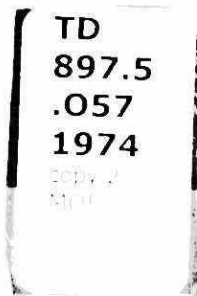
177
June 1974

962

21st. ONTARIO INDUSTRIAL WASTE CONFERENCE

JUNE 23 – 26, 1974
TORONTO, ONTARIO

PROCEEDINGS



MINISTRY OF THE ENVIRONMENT

The Honourable
William G. Newman,
Minister

Everett Biggs,
Deputy Minister

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

PROCEEDINGS
OF THE
21ST ONTARIO INDUSTRIAL WASTE
CONFERENCE

HELD AT
THE SKYLINE HOTEL, TORONTO, ONT.

JUNE 23 - 26, 1974

C O N T E N T S

	Page
Preface	
K. H. Sharpe Assistant Deputy Minister Environmental Planning & Assessment Ministry of the Environment Toronto, Ont.	1
Land-use Planning, Its Relationship to Environmental Controls and Comments Regarding Quality of Life	3
Dr. E. G. Pleva Professor of the Department of Geography University of Western Ontario London, Ont.	
Recent I.J.C. Activities in Water Resources Management	12
K. A. Oakley Associate Director International Joint Commission Great Lakes Regional Office Windsor, Ont.	
Design and Operation of a Multi-Stage System for Treatment of Poultry Plant Wastewater	35
L. S. Love L. S. Love & Associates Ltd., Process Consultants Brampton, Ont.	
Solving Environmental Problems at a Fertilizer Complex	48
T. B. Lynch Technical Superintendent Canadian Industries Ltd., Lambton Works Courtright, Ont.	

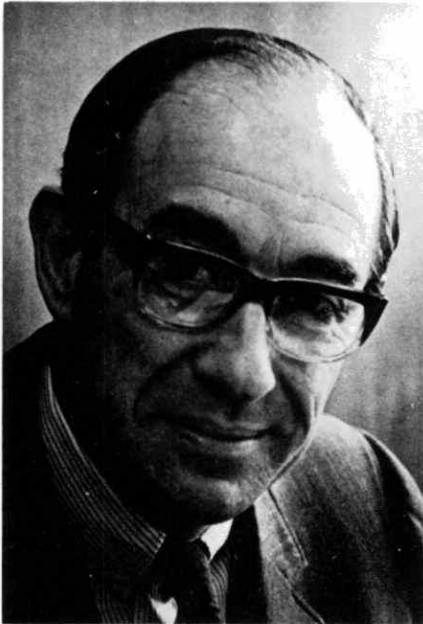
	Page
A Progress Report on a Primary Waste Treatment Clarifier in an Integrated Kraft and Fine Paper Mill	58
O. Kristiansen Domtar Fine Papers Ltd., Cornwall, Ont.	
J. R. McCallum Domtar Fine Papers Ltd., Cornwall, Ont.	
Dr. L. Behie Senneville Research Group Domtar Fine Papers Ltd.	
A Resource Recovery Centre Incorporating A Full Scale Experimental Waste Reclamation Plant	73
J. K. Walter Special Projects Engineer Kilborn Engineering Ltd., Consulting Engineers Toronto, Ont.	
The Management of Concentrated Liquid Waste & Solid Waste in Industry	82
O. V. Martini James F. MacLaren Limited Environmental Engineers and Scientists Willowdale, Ont.	
D. Sexsmith James F. MacLaren Limited Environmental Engineers and Scientists Willowdale, Ont.	

	Page
Landfill Contaminant Flux - Surface & Sub- surface Behaviour	98
F. A. Rovers Engineer Hydrology Consultants Ltd., Mississauga, Ont.	
J.P. Nunan President Hydrology Consultants Ltd., Mississauga, Ont.	
Dr. G. J. Farquhar Associate Professor Dept. of Civil Engineering University of Waterloo Waterloo, Ont.	
Sulphur Dioxide Removal Systems Related to Ontario Hydro	119
D. Harrison Managing Engineer Pollution Abatement Programs Ontario Hydro Toronto, Ont.	
Inco's SO ₂ Emission Control Program - Past, Present and Future	133
K. Segsworth Supervisor, Air Management Ontario Division International Nickel Co., Ltd., Sudbury, Ont.	

	Page
Extensive and Intensive Lake Studies in the Sudbury Area	138
N. Conroy Chief, Water Resources Ministry of the Environment Sudbury, Ont.	
L. Maki Biologist Ministry of the Environment Sudbury, Ont.	
Environmental Aspects of Acid Mine Wastes	144
M. German Biologist Technical Support Section Regional Operations Division Ministry of the Environment	
Toxicity Studies Relating to Acidic Conditions in Lake Systems	158
G. R. Craig Limnology & Toxicity Section Water Resources Branch Ministry of the Environment	
Restoration of Acidified Lakes, Middle and Lohi, in the Sudbury Area	163
M. F. P. Michalski Supervisor Limnology & Toxicity Section Water Resources Branch Ministry of the Environment	
J. Adamski Scientist Water Quality Section Ministry of the Environment	

	Page
An Economic and Environmental Model for Planning and Forecasting	176
Dr. P. A. Victor Senior Economist Environmental Approvals Branch Ministry of the Environment Toronto, Ont.	
Construction and Operation of a Mining Complex in an Urban Area	183
C. H. Frame Vice-President & General Manager Tara Mines Limited Navan County of Meath, Ireland	
The Recovery and Treatment of Spent Rolling Solutions at The Steel Company of Canada, Ltd., Hilton Works Operation	220
A. A. Schuldt Senior Utilities Engineer V. A. Suffoletta Assistant Utilities Engineer	
21 Years - A Look at The Industrial Waste Conference	231
D. S. Caverly Chairman Environmental Hearing Board Toronto, Ont.	
Appendix	
List of Delegates who attended the 21st Ontario Industrial Waste Conference	

P R E F A C E



K. H. SHARPE
Assistant Deputy Minister
Environmental Planning & Assessment
Ministry of the Environment

CHAIRMAN,
Ontario Industrial Waste
Conference Committee

The fact that the attendance at our annual Industrial Waste Conference is maintained at a high level each year confirms our viewpoint that this Conference provides a most useful forum for the exchange of information on problems related to the protection of the environment. With the expansion of the program this year to include subjects dealing with air and solid waste management, in addition to water pollution control, the Conference now operates on a broader environmental base and will, we are confident, generate even wider interest in the future.

The Proceedings of the 1974 Conference have now been bound and are being forwarded to you for your information and convenient reference.

If additional information is required, please direct your enquiry to the OIW Conference Committee, 135 St. Clair Avenue W, Toronto M4V 1P5.

The Conference Committee would like to express its appreciation to those persons who presented papers this year and who led in the discussions. A list of those who attended appears as an Appendix to these Proceedings.

We hope that we shall have the pleasure of seeing you at next year's Conference.


Conference Chairman

1974 ONTARIO INDUSTRIAL WASTE
CONFERENCE COMMITTEE

K. H. Sharpe,	Chairman
D. P. Caplice,	Program Convener
J. B. Patterson,	Program Convener
M. J. Cathcart,	Secretary



CHAIRMAN - SESSION I
MR. R. E. E. COSTELLO
SENIOR VICE-PRESIDENT
CORPORATE SERVICES
ABITIBI PAPER COMPANY LIMITED
TORONTO, ONTARIO

R. E. E. COSTELLO

"Land-Use Planning, Its Relationship
to Environmental Controls and Comments
Regarding Quality of Life"

BY

DR. E. G. PLEVA

Professor of the Department of Geography
University of Western Ontario
London, Ontario



E. G. PLEVA

I. Ontario's Planning Legislation

Ontario has a fortunate history of experience with environmental planning legislation. Three packages of legislation have served Ontario well.

1. The Conservation Authorities Act enabled municipalities to organize on a regional scale to deal with certain regional problems that could not be handled on a fragmented local basis.

2. The Planning Act enabled municipalities to organize and manage the development of urban expansion.

3. The Water Resources Commission Act enabled municipalities to organize and manage the assembly, distribution, use, and recycling of water, a fundamental environmental resource.

The Province is a partner in all the operations of these planning-sensitive packages of legislation. The Province provides sponsorship, technical cooperation, financial assistance, and managerial assistance in varying degrees in all the planning processes and activities.

II The Challenge of 1975

Ontario has reached a developmental stage where the need for a provincial land use policy is apparent. It is not enough to say, as was said in the past, that Ontario's land use policy was what Ontario did from day to day. The philosophy of Ontario's "official plan" processes, which has had a quarter-century of productive operation, must pervade a necessary thinking process to achieve an operational "official plan" for Ontario. The kind of "official plan" thinking that the Province has asked local and regional governments to do for themselves must now be done at the provincial level as well.

The Province must work toward the speedy evolution of a land-use policy to make certain that land use decisions make environmental as well as economic sense, both for the present and the future.

Ontario is a mosaic of legitimate land uses. The task is to put together the necessary land uses in compatible patterns, so that the maximum benefits may be derived from the total resource base. The philosophy of "development control", properly applied, will make certain that any land use change from an existing use will be subject to honest review and appraisal. The process, properly used, is an incentive to wise use and development.

The complexity of the problem is apparent. However, Ontario has had the necessary experience and leadership to provide significant idea leadership to the rest of North America in the field of land use policy and resources development. Most important of all is that Ontario has developed a select cadre of professional scientists and technicians who can develop the important information to enable elected officials to make good decisions regarding present and future uses of resources.

To indicate the complexity of the problems related to the making of good land use and resources decisions, it is necessary only to catalog a few of the important sectors of the environmental matrix.

1. Urban development areas present a wide spectrum of demanding problems. Where are the urbanizing corridors? How do we designate and manage the growth centres? What is the role of the dormitory town? What is the rationale for developing "new towns"? How do we balance commercial, industrial, residential and recreational land uses in human settlements? It is important to realize that the United Nations Conference on Human Settlement will be held in Canada in 1976. The rest of the world will look to see what we have done. On the other hand, we will be able to exchange information and new knowledge with people from other countries who are facing problems similar to ours.

2. Agricultural land is the scarce land commodity in Ontario. Much of the best food and fiber-producing land we have or ever will have is in the shadow of rapidly expanding non-agricultural pressures. The pressures for land use change are not coming from the agricultural sector. A firm policy related to high capability agricultural land must be set before 1980.

3. Many areas of Ontario are related to primary productions other than agriculture. The two major land and resources uses are forestry and mining, including quarrying. The problems related to the maintenance of sustained yields are complicated. Ontario, however, has the necessary intellectual resources to deal with the problems.

4. Recreational lands are necessary in both the private and public sectors of ownership. Much of the recreational land use needs can be managed on a multiple-purpose basis with other legitimate land uses.

5. Special areas require special measures. Ontario's scenic, historical, and ecologically-important sites and habitats must be planned carefully so that their special functions and capabilities may be enhanced rather than retarded by their relationship

to other land uses in the total land use pattern. Many land use areas necessary to today's complex settlements must be related carefully to the total living space. There are many examples: spray waste water irrigation sites, "sanitary" land fill sites, nuclear power sites, and so on.

6. Ontario is a well-watered Province with thousands of miles of coastal, lakeshore, and riparian frontage. We have reached a critical time in dealing with the problems related to the management of the critical coastal, lake front, and river bank problem. Immediate attention must be made to the shorelands of the Great Lakes. Ontario is not alone in recognizing the need for action regarding the wise use of the Great Lakes coastal zone. The International Joint Commission intends to move rapidly to deal with this pressure problem which Ontario shares with eight states across the international boundary. Ontario has given idea leadership in the management of flood plain lands. While other parts of North America talked, Ontario acted. The concept of a floodway zone in the official plan that implies eventual public ownership and management of the hazard lands of the floodway is well established in Ontario. The most effective way to deal with the flood hazard problem is to keep settlements and installations out of the flood plain.

7. More attention must be paid to the significance of transportation and utility corridors. The complexities of the problem are overwhelming; yet the intellectual capabilities to deal with the problems are available. Is it possible to consolidate linear entities into defined corridors? What elements are compatible; which are incompatible? Is it possible to combine a 500 KV electrical transmission line with a 400 class freeway? Probably not. But, actually, how much do we know about the energizing and connective corridors which bind Ontario together? This short list of the linear or corridor elements will indicate the complexity of the problem.

1. Railways
2. Highways and Roads, including Parkways
3. Electrical transmission lines, particularly the 500 KV network joining generating centres with consuming areas.
4. Pipelines: water, petroleum, natural gas, and "products" lines (gas, liquid, solids).

5. Telecommunications, including transmission lines, cables, and beam systems with their attendant towers.
6. Canals and canalized rivers with the necessary systems of locks and water level maintenance; port installations.
7. Hiking trails and pedestrian paths.
8. Airports and their ancillary installations.

8. The need to provide industrial parks and industrial-intensive areas is being recognized acutely by regional governments. The relationship of these job-producing areas to the residential areas is a prime requisite in dealing with regional development programs. Where will people work? Where will they live? What is the significance of the "journey to work" constraint on traffic planning?

9. Where will the military installations be located? We live in an unbalanced world and the need for defence will persist throughout our present generation at least. Is it possible that certain military installations may be converted to other uses?

10. Government (local, regional, provincial, federal, international agencies) is demanding in its land use needs. How may we organize governmental functions and services spatially so that the resultant land use patterns will be positive rather than negative.

III The Fact Of Concentration in Ontario

Ontario is the most urbanized Canadian province. In 1961, 77% of us lived in urban environments. By 1975, this figure rose to 83%. By 1980, 86% of us will be urban based.

Most of this concentration is in the Grand Trunk Corridor, a narrow bundle of transportational opportunities that connects the salt-water estuary of the St. Lawrence River at Quebec City with the heart of the continent in Chicago. The Ontario sector, sometimes called the Seaway Corridor, links Montreal through Cornwall, Kingston, Toronto, Hamilton, and London with Windsor on the Detroit River frontier. In 1961, 54% of all people in Ontario lived in the

narrow corridor across the southern edge of the Province. By 1974, the figure had risen to 60% (of 8 million). By 1980, 65% (of 9 million) of all people in Ontario will live in the Ontario portion of the Grand Trunk corridor. This means that two-thirds of the people of Ontario will live in a narrow strip that totals less than 10% of the total area of the Province (actually only 7%). The planning implications of these simple statistics are obvious.

Thus, the most important question facing us today is, "although we have a fairly good idea where the next million people of Ontario will live, how will they live? What about housing and its availability? What do we want in the design and the shape of human settlement? What are we likely to get? How does mobility accelerate the rate at which the shape of human settlement patterns may change?

Cities in the corridor tend to grow toward each other. In what ways may the trend toward regional government be effective in managing the evolving megalopolis in southern Ontario.

Cities change in many ways. They grow on the edges (suburban growth); they fill in (including growing upward); and they renew themselves (like a hockey team changing on the go). Are these processes manageable? Can we keep our cities with tidy hems rather than with sprawling edges. Where do "new towns" fit into an urban strategy for Ontario?

IV Five Research and Operational Challenges

It is evident that our research priorities must be related to the needs of an urbanized, highly industrialized Ontario in which agriculture, mining, forestry, and recreation have important and legitimate space demands for their productive activities. At least five challenges may be recognized:

1. We must be more proficient in the arts and skills of growing a city.

2. We must know more about urban space in human terms. We must understand more fully the implications of density control. We must explore the

implications of the concepts related to optimum size.

3. We must develop a strategy that harmonizes physical planning, social planning, and environmental planning.

4. We must understand centrifugal and centripetal forces in order to achieve and manage effective patterns of development on regional, provincial, and national scales. The real effect of improved transportation networks must be understood.

5. We must seek effective ways to combine fixed systems, such as land, with flow systems, such as transportation networks. Flow energizes a system.

V London, Ontario, as an Example of Flow System Management

London, Ontario is an example of the way a flow system is developed and managed. The key factor is related to the water cycle.

London's water supply story is similar to that of many other municipalities. In the beginning, there were shallow wells, then the corner pump, followed by elemental systems based on springs. London, by the turn of the century, began to exploit the basal gravels by sinking deep wells. After World War II, the search for additional supplies was begun. All alternatives were tested: the lake behind Fanshawe Dam, water spreading in the Fanshawe area, the drilling of deep wells in the Komoka area and the White Oaks area. Additional deep wells were sunk in the existing field. Finally, the decision was made to go to Lake Huron. The system that evolved has proved to be a "dream system". The details are well known to everyone interested in water supply. The London region has a system in place that can satisfy the needs of five million people with only modest per capita outlays for extensions to the present system already in operation. One wonders why there was so much opposition to the proposal when first presented.

The solving of the water supply problem,

however, did not solve London's water cycle problem. There is the problem of sewage treatment and disposal. London is an inland city that uses its Thames River as the receiving body of its effluent. London's system of sewage treatment is technologically advanced but nothing can change the basic characteristics of the Thames River, particularly its summer flow volumes. Thus, the City of London must face the possibility of a limit to growth being imposed.

Discussions and inquiries are underway to test the alternatives available. First, the system could be brought up to the highest possible level for secondary treatment systems. This, in itself, is not enough. The City could go to a tertiary, or even to a completely sophisticated quaternary system. The costs of this course must be ascertained. The effluent from the secondary treatment system could be sprayed on cropland or forested land. The general feeling is that the cropland solution is too close to the food chain and should not be used. The forested land system will be explored fully. Of course, the effluent could be piped to Lake Erie. The quality of the effluent is higher than expected from Detroit, Cleveland, or Buffalo in the next decade. However, many scientists and political leaders in London are playing leadership roles in the drive to clean the Great Lakes. It is evident that London will not pipe its effluent to Lake Erie. A few proponents argue that Toronto, Sarnia, Hamilton and Windsor are blessed with adjacent high volume receiving bodies of water and that inland municipalities should not be deprived of similar opportunities. Pipelines are constructed easily today and can be financed easily under municipal financing practices.

It is obvious the London solutions to the effluent disposal problem will be as productive to the technology and economics of dealing with the water cycle as have been London's well documented search for an abundant water supply. London is a test city in many ways. Once again, a solid body of data related to environmental planning will develop in the London area.

It is important to emphasize that we need solid information related to the water supply and waste treatment problems related to urban growth and

development. The economics of the "water cycle" in resources and environmental terms is still an uncertain area of inquiry.

VI Conclusion

We, as practitioners in the arts and sciences of environmental planning, have our specific duties which we carry out conscientiously. However, we must remind ourselves constantly of the importance of what we do in our specific tasks to the total global system of which our work is but a part.

Secretary General Waldheim of the United Nations said recently that there are six great world crises: mass poverty, world population, food, energy, military expenditure, world monetary system. Those scientists and technologists such as you who work daily with the problems of environmental planning are very close to the programs the world needs to deal effectively with its six great crises.



"Recent I.J.C. Activities in Water
Resources Management"

BY

K. A. OAKLEY

Associate Director

International Joint Commission

Great Lakes Regional Office

Windsor, Ontario

K. A. OAKLEY

INTRODUCTION

The Boundary Waters Treaty 1909 between the United States and Canada provided for the establishment and maintenance of the International Joint Commission. The Treaty included a clause which obligated both countries not to pollute Boundary Waters. In recognition of the pollution of the waters of the Lower Great Lakes and in response to the I.J.C.'s recommendations to remedy the situation, the Great Lakes Water Quality Agreement between the United States and Canada was signed on April 15, 1972 by President Richard M. Nixon and Prime Minister Pierre E. Trudeau.

This paper presents the function, structure and activities of the Commission, as well as the various bodies which have been developed to assist and advise the Commission in the discharge of the new obligations assigned to the Commission under the terms of the Great Lakes Water Quality Agreement.

BOUNDARY WATERS TREATY 1909

The preamble to the Treaty states:

"Being equally desirous to prevent disputes regarding the use of boundary waters and to settle all questions which are now pending between the United States and the Dominion of Canada involving the rights, obligations, or interests of either in relation to the other or to the inhabitants of the other, along their common frontier, and to make provision for the adjustment and settlement of all such questions as may hereafter arise..."

Boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and Canada passes, including all bays, arms and inlets thereof. Boundary waters do not include tributaries or water flowing from these lakes, rivers and connecting waterways or waters of rivers flowing across the boundary.

The Treaty provided for the establishment and maintenance of an International Joint Commission which was given "jurisdiction over and shall pass on all cases involving the use or obstruction or diversion of the waters..."

The exercise of jurisdictional powers by the Commission is governed by a broad but specific set of rules and an order of precedence for conflicting use of water. This order of precedence is :

- (1) Uses for domestic and sanitary purposes.
- (2) Uses for navigation, including the service of canals for the purposes of navigation.
- (3) Uses for power and irrigation purposes.

The Treaty laid down general rules to be observed by both countries and the Commission. While all of these rules are applicable to water quality management, those of particular interest for this paper are:

Both countries shall have, each on its own side of the boundary, equal and similar rights in the use of boundary waters.

Boundary waters, or waters flowing across the boundary shall not be polluted on either side to the injury of health or property of the other.

THE INTERNATIONAL JOINT COMMISSION

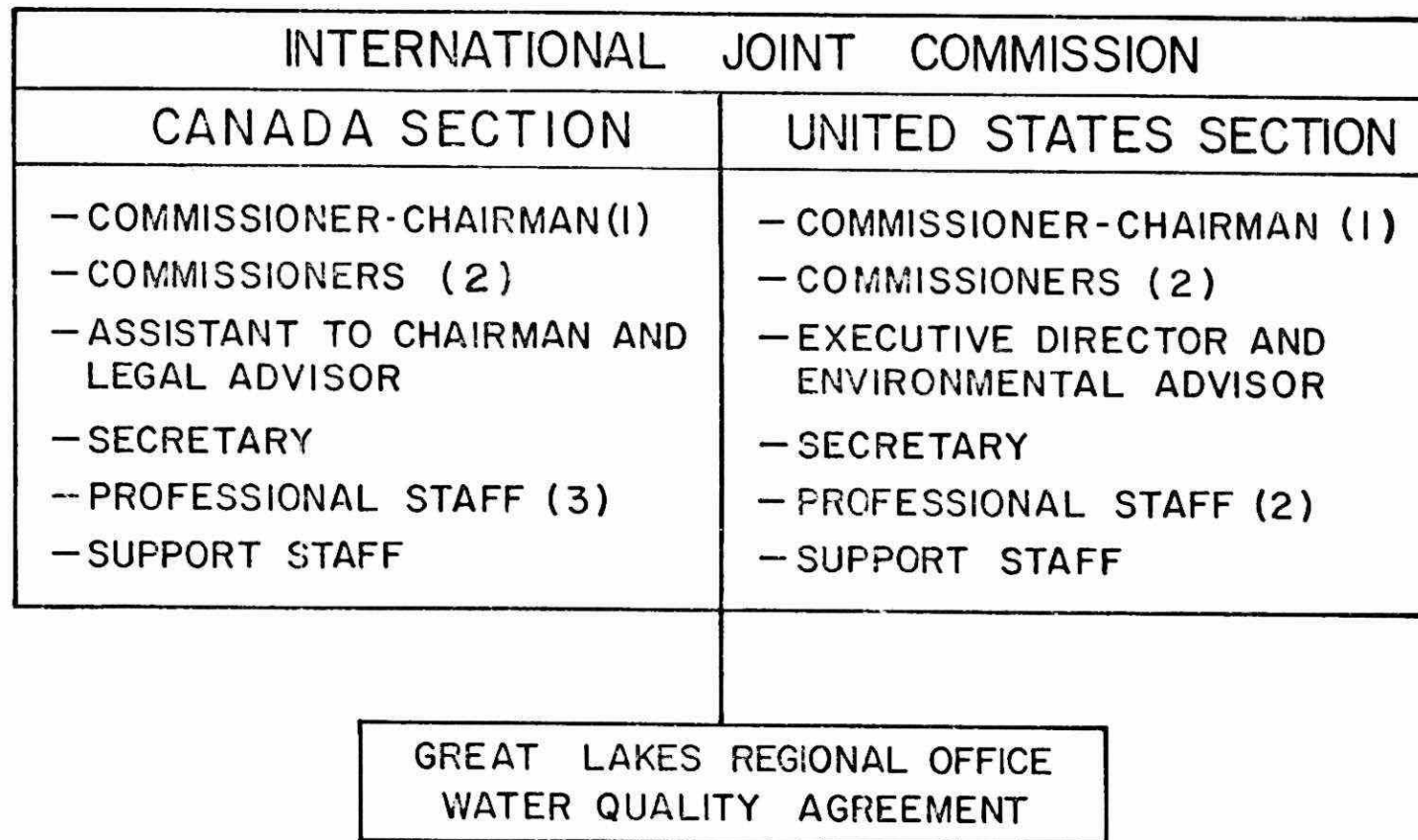
The Commission (Illustration #1) is composed of two sections--the Canadian Section, a Chairman and two Commissioners, and the United States Section with a Chairman and two Commissioners also. However, the Commission is a unitary body with decisions taken by simple majority. The Sections are not under instructions by their respective governments.

The United States Section's membership is comprised of Mr. Christian A. Herter, Jr., Chairman, Mr. Victor L. Smith and Mr. Charles R. Ross, Commissioners.

The Canadian Section's membership is comprised of Mr. Maxwell Cohen, Q.C., Chairman, Mr. Bernard Beaupré and Mr. Keith A. Henry, Commissioners.

CANADA - UNITED STATES

BOUNDARY WATERS TREATY 1909



In the exercise of its function, the Commission maintains a limited staff at each of its section headquarters in Ottawa and Washington. Reliance is placed on the two federal governments, state and provincial governments to provide the services of engineers, scientific and support personnel to conduct studies, investigations, surveillance etc. The headquarters staffs provide legal, engineering and administrative support to their respective sections of the Commission.

The Commission appoints International Boards, composed of specially qualified personnel from the Government sources, to conduct investigations, maintain surveillance or ensure compliance with its Orders of Approval.

Boards of Control

It is required by the Treaty and is normal practice for the Commission that public hearings be conducted in the localities affected by the problem under study. Following hearings of an application for approval of a use, obstruction or diversion of water, the Commission may issue an Order of Approval which prescribes certain conditions for the protection or indemnity of various interests. In such cases, it appoints an International Board of Control to ensure that the applicant complies with all the terms of the Order of Approval. There are some thirteen Boards of Control active currently.

Pollution Surveillance Boards

International Pollution Surveillance Boards maintain active interest in water and air pollution following completion of International Joint Commission's investigations and submission of reports to governments. Included in this group is the Board which continues to monitor and obtain technical data on air pollution in the area of the St. Clair and Detroit rivers and elsewhere along the international border in order to bring to the Commission's attention air pollution problems along the boundary that may require action by governments.

Investigation Boards

The Commission establishes Boards of specially qualified officials from government agencies in both countries to plan and coordinate the necessary technical studies and to report with recommendations. A wide range of matters have been referred for investigation. These include the total power potential of Passamaquaddy Bay on the east coast, the water resources of the Columbia River in the west, the preservation of the scenic splendor of the falls at Niagara, the feasibility of further regulating the levels of all the Great Lakes.

POLLUTION OF BOUNDARY WATERS

The Commission was requested, as early as 1912, by the two governments to determine to what extent, by what causes and in what localities were the boundary waters between the two countries, including the Great Lakes, polluted, so as to be injurious to public health. This request was prompted by a prevalence of typhoid fever. The Commission, after consideration of the bacteriological oriented study, concluded that pollution was intense along the shores of the Detroit and Niagara rivers. The Commission recommended that it be granted jurisdiction to regulate and prevent such pollution in the Basin. A convention was drafted in 1920 toward this end but for various reasons was not negotiated to completion. The advent of chlorination may have been one of these reasons.

Following World War II, the Commission was requested to examine the pollution problems of the Connecting Channels of the Great Lakes (the St. Mary's, St. Clair, Detroit and Niagara rivers). The growth and concentration of population and industry had created large volumes and new types of waste discharges. A comprehensive study was conducted. The Commission in 1950 set forth specific water quality objectives for adoption by the governments and recommended that it be authorized to establish and maintain continuing supervision over the quality of these waters to ensure achievement of the objectives. Its recommendations were approved setting a precedent for international water quality objectives reflected in the pollution abatement programs of enforcement agencies by both countries.

The increased quantity and different composition of municipal and industrial wastes, as well as the residual characteristics of materials discharged into the lakes during the post World War II years, led to extensive biological change in the Lower Great Lakes. Thus, in 1964 the governments requested the Commission to inquire into and report upon the condition of the waters of these lakes and the international section of the St. Lawrence River.

The Commission submitted its final report to the governments in January 1971. This report indicated that the Lower Great Lakes were being seriously polluted mainly by municipal and industrial wastes. It provided the basis for concrete remedial action, on the part of the Federal, State and Provincial governments concerned, in the form of nineteen conclusions and twenty-two recommendations. The recommendations proposed the adoption by the governments of Canada and the United States of Water Quality Objectives for the Lower Lakes and Connecting Channels and the immediate reduction of the phosphorus content of detergents, as well as many other measures directed toward the prevention of pollution of the Great Lakes System.

GREAT LAKES WATER QUALITY AGREEMENT

On April 15, 1972, President Nixon and Prime Minister Trudeau signed the Great Lakes Water Quality Agreement at Ottawa.

The Agreement resulted from extensive discussions and negotiations between the two Parties based on the recommendations in the Commission's 1970 report. The Province of Ontario played a leading role in these activities which also involved the Great Lakes States on the United States side.

The Agreement sets forth general water quality objectives for the boundary waters of the Great Lakes System as well as specific water quality objectives. It stipulated that programs and other measures directed toward the achievement of these objectives be implemented as soon as practicable and that, unless otherwise agreed, these be completed or in the process of implementation by December 31, 1975.

The Agreement requires that the Parties consult on the recommendations contained in each report submitted by the International Joint Commission and consider appropriate actions.

The Agreement requires that all reasonable and practicable measures shall be taken to maintain the water quality in those areas of boundary waters where the specific objectives are exceeded, i.e. the quality is better than the agreed objectives would require.

In recognition that the objectives cannot be met, over the short term, in certain areas such as harbours, "localized areas" may be designated by the responsible agency. Such areas are to be identified specifically and kept to a minimum. Existing land use and land activities prevent the objectives from being met at least over the short term.

Illustration #2 shows the organization relationship of the Boards and Water Quality Agreement Institutions with the International Joint Commission.

THE INTERNATIONAL JOINT COMMISSION'S RESPONSIBILITIES

The International Joint Commission was assigned responsibilities to assist in the implementation of the Agreement and in order to do so was given certain new powers and functions.

Its responsibilities include the collation, analysis and dissemination of data and information supplied by the Parties, State and Provincial governments relating to the quality of the boundary waters and to

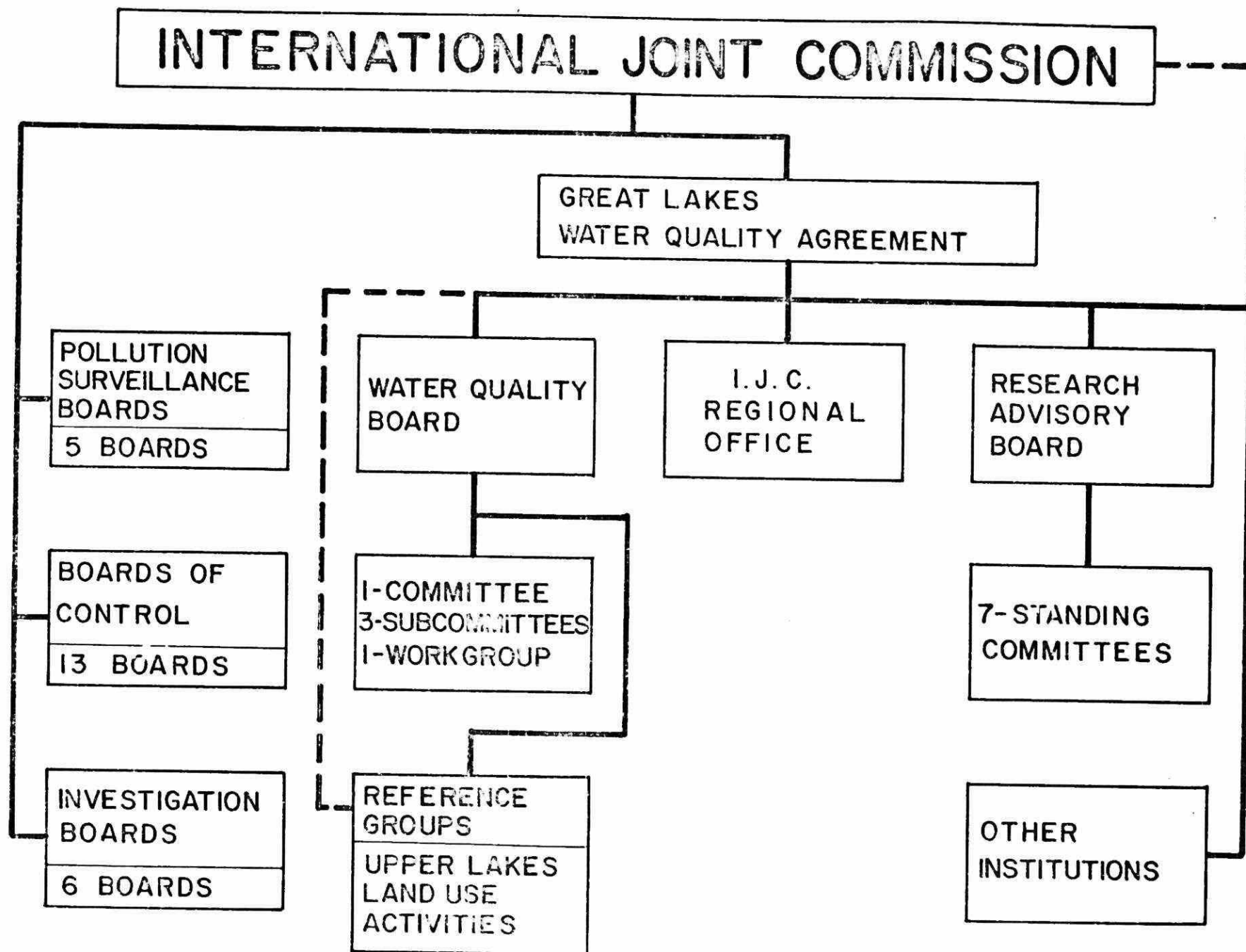


Illustration # 2

pollution entering from the tributaries; the collection, analysis and dissemination of data and information concerning the water quality objectives and the operation and effectiveness of the programs and other measures established pursuant to the Agreement.

The Commission is charged with the responsibility of tendering advice and recommendations to the governments concerning water quality objectives, legislation, standards, regulatory requirements, programs and inter-governmental agreements.

The Commission is also to provide assistance in the coordination of the joint activities, including such matters as contingency planning, consultation on special situations and coordination of Great Lakes water quality research.

The Commission is authorized to use its full powers granted under the Boundary Waters Treaty, and legislation pursuant thereto, which includes the power to conduct public hearings and to compel the testimony of witnesses and the production of documents.

The Commission is required to report no less frequently than annually to the Parties and to the State and Provincial governments on the progress toward the achievement of the water quality objectives with an assessment of the effectiveness of the programs and other measures and including advice and recommendations. It may make special reports any time to the governments and the public.

The Commission is authorized to publish any report, statement or document prepared by it at its discretion relating to its functions under the Agreement.

The Commission is also authorized to verify, independently, the data and other information supplied by the Parties, and by the State and Provincial governments through appropriate means but consistent with the Boundary Waters Treaty and with applicable legislation.

The Parties specifically requested the Commission by formal references under the Boundary Waters Treaty to enquire into and report to them upon:

- (1) The pollution of the boundary waters of the Great Lakes System from agriculture, forestry and other land use activities.
- (2) The actions needed to preserve and enhance the quality of the waters of Lake Huron and Lake Superior.

BOARDS AND OTHER JOINT BODIES

Water Quality Board

Illustration #3 shows the organizational structure of the Water Quality Board.

The Agreement required that the Commission establish a Great Lakes Water Quality Board composed of an equal number of members from Canada and the United States representing the Parties, each of the eight Great Lakes States and the Provinces. This resulted in an eighteen member Board. The members were appointed by the Commission after consultation with the appropriate Government.

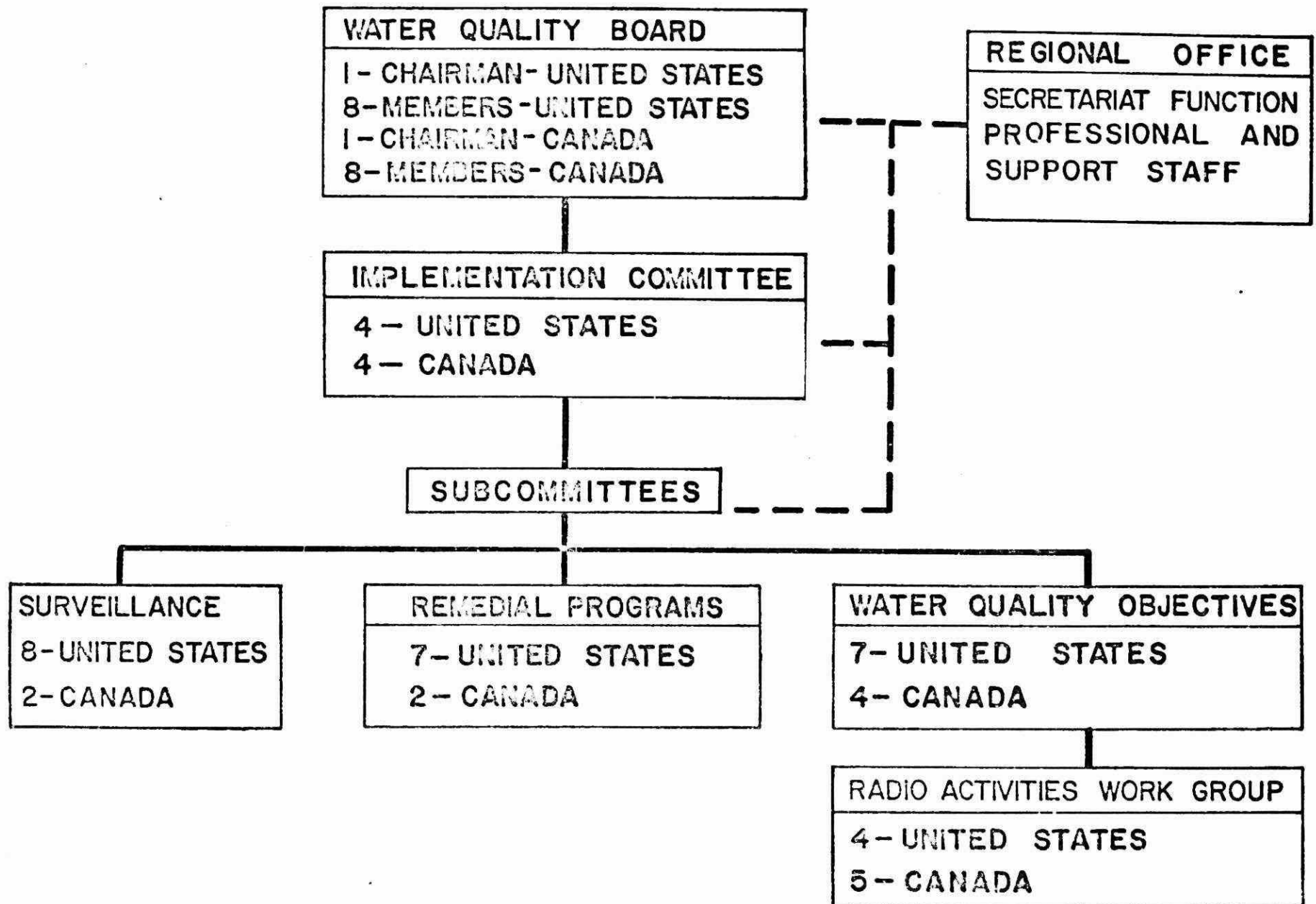
Appointments to the Board have been at the senior administration level in both the United States and Canada. The U.S. Chairman is Mr. F.T. Mayo, the Administrator for Region V, Environmental Protection Agency, Chicago. State representatives are at the Director/Administrator level. The Canadian Chairman is Dr. A.T. Prince, formerly Director General, Inland Waters Directorate, and now an Assistant Deputy Minister of the Energy Mines and Resources Department. Three additional members represent the Canadian Federal Government, Ontario has four members, and Quebec one member.

The Water Quality Board has been directed by the Commission to be its principal advisor with regard to the exercise of all the functions, powers and responsibilities (other than assistance in the coordination of research) assigned to the Commission under the Agreement. It is required to carry out such other functions, related to the water quality of the boundary waters of the Great Lakes System, as the Commission may request from time to time.

The Board has also been directed to keep itself informed of joint activities envisaged by the Agreement and to advise the Commission if, in its opinion, the Commission's assistance in any such activities, by coordination or otherwise, would be beneficial.

In order to discharge its responsibility to the Commission, the Board has established an Implementation Committee and three subcommittees which receive direction from and report through the Implementation Committee. Each of the three subcommittees have been delegated responsibility for a major activity under the Agreement, namely: Remedial Programs, Surveillance and Water Quality Objectives. The committees began operations late in 1973 and provided considerable input into the Second Annual Report of the Water Quality Board. It is noted that the membership of the subcommittees is not in balance as between the United States and Canada. The reason for this

GREAT LAKES WATER QUALITY AGREEMENT



is simply that the State and Provincial governments have the major jurisdictional role in the operational management of programs directed toward the prevention and control of water pollution and, except on the open lakes, the direction, management and/or operation of monitoring networks and programs. Thus the lack of balance between the United States and Canada representation is essentially numerical only.

Procedures for the submission to the Water Quality Board and the exchange of data from and between the Federal, State and Provincial governments have been adopted. The complexity and volume of data, the great number of government departments and the large number of people involved in preparing reports to meet the Water Quality Agreement requirements for the first time provided a major learning experience for committee members and Regional Office staff during the months of January, February and March 1974, when the Board's Report for 1973 to the Commission was being prepared.

Research Advisory Board

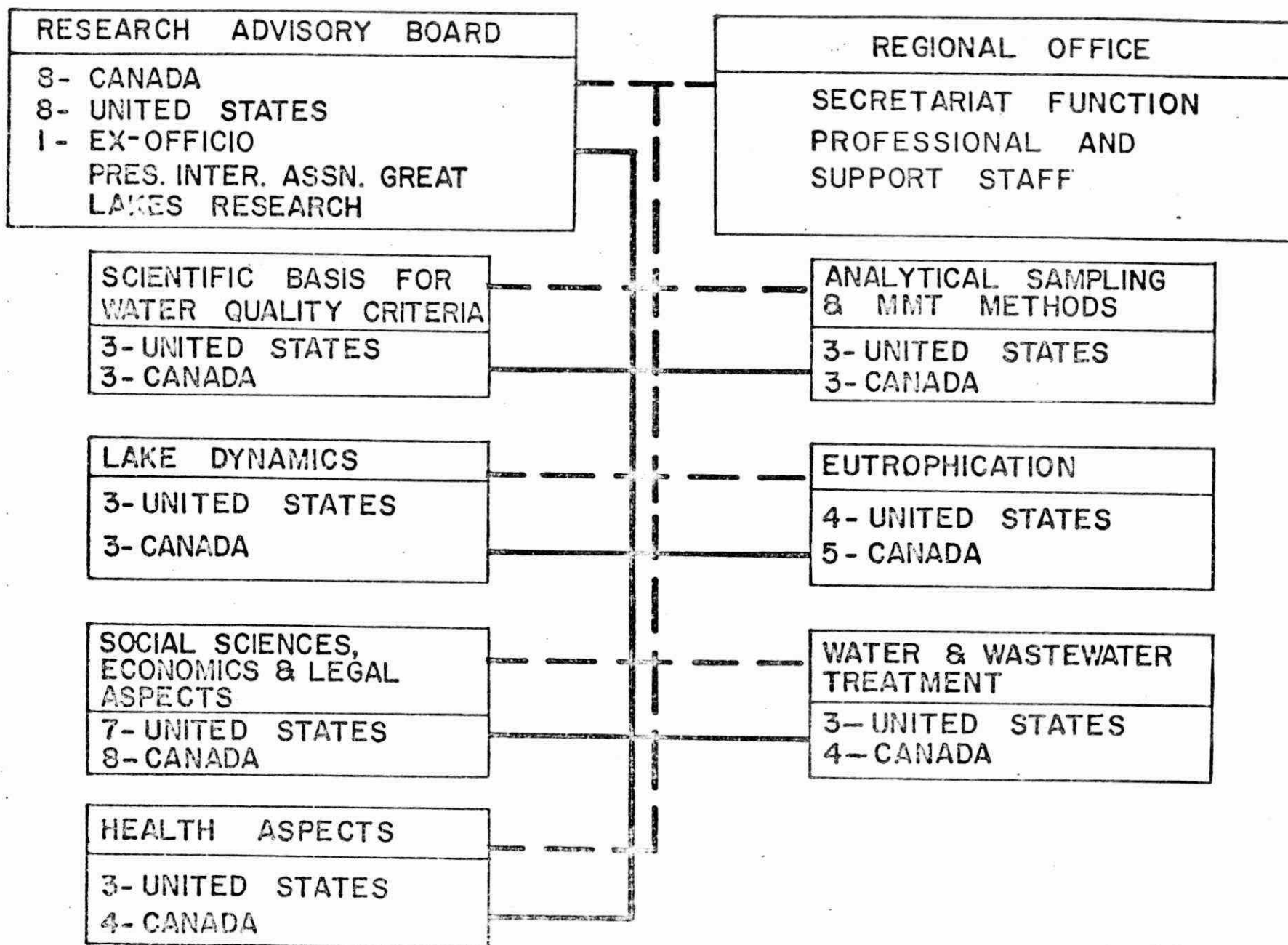
The Research Advisory Board (Illustration #4) was established by the Commission in accordance with specific Terms of Reference included in an annex to the Agreement. This Board is responsible for reviewing at regular intervals the research activities in the United States and Canada concerning Great Lakes water quality in order to examine the adequacy and reliability of research results, to identify deficiencies, additional projects and specific research programs. The Research Advisory Board is the principal adviser to the Commission on the coordination of Great Lakes water quality research and the dissemination of such research information to interested persons and agencies.

The Chairman of the United States Section is Dr. A.F. Bartsch, Director, National Environmental Research Centre, Environmental Protection Agency, and the Chairman of the Canadian Section is Mr. J.P. Bruce, Director, Canada Centre for Inland Waters.

The Board held its first meeting on November 20, 1972 and up to April 1974 has held seven meetings at various locations within the Great Lakes Basin.

In order to enable the Board to achieve the objectives of the charge previously outlined, the Commission appointed a relatively small membership of senior research managers and scientists with broad experience from governments as well as representatives of industry, university and community-at-large. Appointments are made for three years which should permit the infusion of new ideas and concepts. The Board has seventeen members,

GREAT LAKES WATER QUALITY AGREEMENT



eight from Canada and eight from the United States, with the President of the International Association for Great Lakes Research as an ex-officio member.

The Research Advisory Board has, assisted by its committees, provided advice to the Water Quality Board and to the Commission. It has prepared a synopsis of a number of research needs which has been distributed to the research community for comment. These needs propose areas of research for new or additional research in such fields as (1) practical microbiological indices to protect recreationists from enteric, upper respiratory tract and epidermal infections, (2) impact of temperature changes on the ecosystems, (3) the obtaining of realistic estimates of impact of nutrients and chemical contaminants from precipitation and dustfall.

Seven committees have been established and are now providing significant input to the Board. Each committee has a membership which is representative of the best expertise available both in Canada and the United States. The work of the committees is exemplified by their recent recommendations on (1) substitution of specific conductance for conventional gravimetric determination of total dissolved solids in the open waters of the Great Lakes and (2) that significantly greater emphasis be placed on research concerning potential epidemiological hazards of waterborne viruses associated with man's activities.

International Reference Group on Land Use Activities

Under the terms of the Boundary Waters Treaty (1909) and the Great Lakes Water Quality Agreement, the Commission was requested to enquire into and report to the two Governments upon the following questions:

- (1) Are the boundary waters of the Great Lakes System being polluted by land drainage (including ground and surface runoff and sediments) from agriculture, forestry, urban and industrial land development, recreational and park land development, utility and transportation systems and natural sources?
- (2) If the answer to the foregoing question is in the affirmative, to what extent, by what causes, and in what localities is the pollution taking place?
- (3) If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgment, be most practicable and what would be the probable cost thereof?

The Reference also requested the Commission to consider the adequacy of existing programs and control measures and the need for improvements thereto, relating to such matters as inputs of nutrients, land use, land fills, deep well disposal, animal husbandry operation.

The Commission made the Water Quality Board responsible for the necessary technical studies and appointed the International Reference Group on Land Use Activities to carry them out under the Board's supervision. Illustration #2 shows the relationship of the Reference Group to the Water Quality Board and the Commission.

Illustration #5 shows the structure of the Land Use Activities Reference Group and its Task Group Technical Committees.

The Reference Group held its first meeting on December 19, 1972 and has held seven meetings up to February 1974. The Task Group Committees have held numerous meetings, both joint and on a national basis. The Group has a total of nine Canadian and nine United States members, each with a Chairman. The Canadian Government and the Ontario Government have four and five members, respectively. Dr. Murray G. Johnson, Director, Great Lakes Bioliminology Laboratory is the Canadian Chairman. The United States Government has two members and each of the Great Lakes States, except Illinois, has one member. The United States Chairman is Mr. Norman A. Berg, Associate Administrator, Soil Conservation Service, United States Department of Agriculture.

The Group presented to the Commission in April 1974 its Third Semi-Annual Progress Report, an Early Action Report and a Detailed Study Plan.

In order to manage this wide ranging study effectively and efficiently, the Reference Group established four major Task Group committees. Each Task Group is comprised of Canadian and United States Sections which operate on a coordinated basis directed toward common objectives.

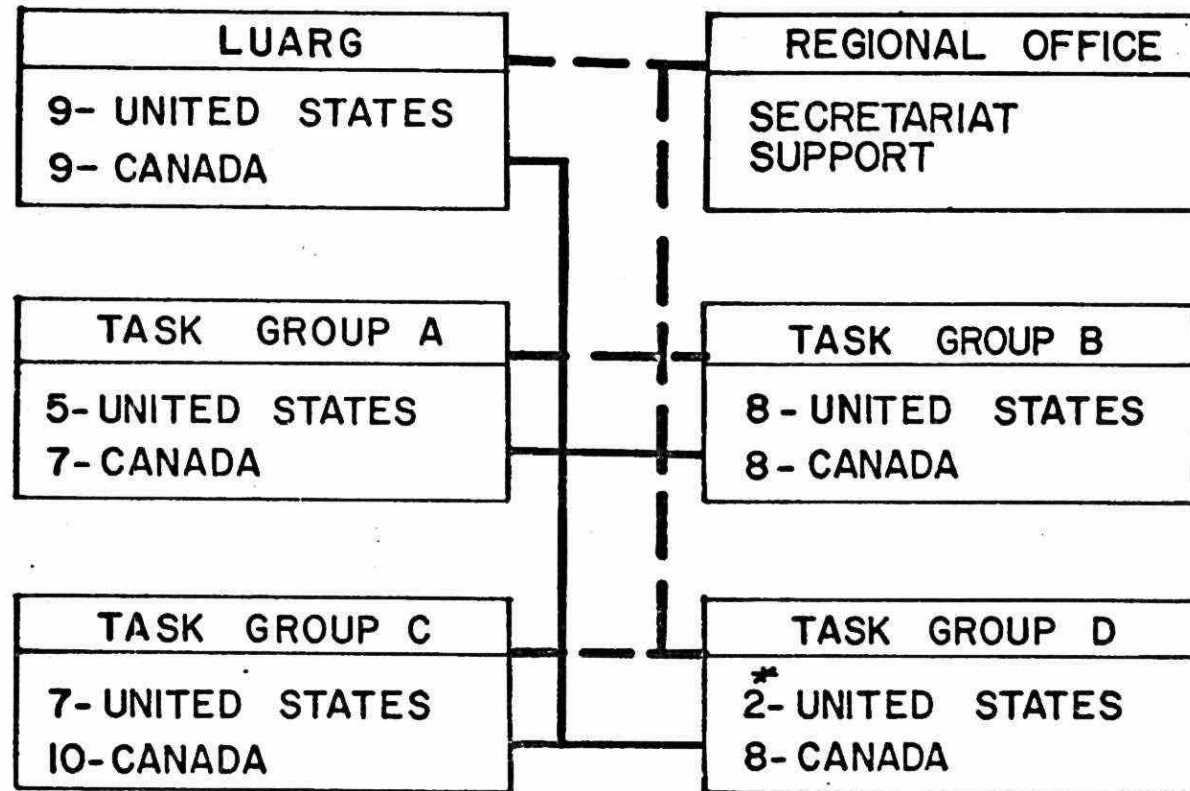
The responsibilities assigned to each of the Task Groups are as follows:

Task A- "To assess problems, management programs and research and to attempt to set priorities in relation to the best information now available on the effects of land use activities on water quality in boundary waters of the Great Lakes."

Progress is being made in both Canada and the United States. In Canada, background documents on Recreation and Forestry have been completed and documents for other land use activities

GREAT LAKES WATER QUALITY AGREEMENT

INTERNATIONAL REFERENCE GROUP ON LAND USE ACTIVITIES



* INCOMPLETE

identified in the preliminary study plans are in the various stages of completion. In the United States, two draft reports for Forestry and Sediments have been completed of a total of seventeen. Completion of all contracts for reports was anticipated to have been completed by May 1974.

- Task B - "Inventory of land use and land use practices and relevant physical data, with emphasis on certain trends and projections to 1980 and, if possible, to 2020."

In the United States, the general land use inventory will be completed by Fall 1974 through the use of machine processing of ERTS-1 satellite data.

In Canada, the Canada Centre for Remote Sensing and Canada Land Inventory are providing considerable input into the completion of this task which is well underway.

- Task C - "Intensive studies of a small number of representative watersheds, selected and conducted to permit some extrapolation of data to the entire Great Lakes Basin and to relate contamination of water quality which may be found at river mouths on the Great Lakes, to specific land uses and practices."

This study, or amalgam of many studies, provides the major component of the Reference Group activities. Detailed study plans have been developed by both the Canadian and United States sections of the study.

Watersheds have been selected for intensive studies in Canada and the United States to cover a wide variety of potential sources of pollution to the waters of the Great Lakes. The selection criteria includes climate, geology, soil characteristics, land uses, and information available from completed or ongoing studies.

Major watersheds selected for study are:

Canada - Grand River draining to Lake Erie
Saugeen River draining to Lake Huron
Wilton Creek draining to Lake Ontario

United States - Genessee River, New York, and Pennsylvania, draining to Lake Ontario
Black Creek, portion of Maumee River, Indiana,

draining to Lake Erie, supplemented by a study in the Ohio portion of the Basin Menominee River, Wisconsin, draining to Lake Michigan

Additional studies are to be undertaken in some areas beyond the major watersheds to determine pollution loads from selected land use activities.

This task is now underway. Because of its magnitude and complexity, a fulltime coordinator is being retained to maximize the benefits which will result from the close coordination of the efforts of Federal, State and Provincial agencies.

Task D - "Diagnosis of degree of impairment of water quality in the Great Lakes, including assessment of concentration of contaminants of concern in sediments, fish and other resources."

Progress has also been made by this Task Group which has prepared detailed study plans for the three activities into which this task has been divided which are:

Shoreline erosion

Survey of river sediments and associated water quality

Effects of land drainage inputs on water quality of the Great Lakes System

In both Canada and the United States, work is now in progress through the contract route and the modification of ongoing programs.

The Reference Group prepared, in February, a detailed study plan of nearly 200 pages which has been approved by the Water Quality Board and the International Joint Commission.

The Group proposes that its final report will be complete in 1977 at an estimated cost of \$10,990,000 (\$5,855,000 in the United States and \$5,135,000 in Canada). In addition, available estimates of the cost of ongoing Government programs relevant to the task of the Reference Group through the Study Period (1973-1977) total \$8,209,000. The funding is being accomplished through the normal procedures of the Provincial, State and Federal governments. In Canada, the International Joint Commission provides a grant to Ontario covering approximately fifty per cent of Ontario's non-ongoing expenditures.

International Reference Group on Upper Lakes Pollution

Under the terms of the Boundary Waters Treaty (1909) and the Great Lakes Water Quality Agreement, the Commission was requested to inquire into and report to the two Governments upon the following questions:

- (1) Are the waters of Lake Superior and Lake Huron being polluted on either side of the boundary to an extent (a) which is causing or is likely to cause injury to health or property on the other side of the boundary; or (b) which is causing or likely to cause a degradation of existing levels of water quality in these two lakes or in downstream portions of the Great Lakes system?
- (2) If the foregoing questions are answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?
- (3) If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable to restore and protect the quality of the waters, and what would be the probable cost?
- (4) In the event that the Commission should find that little or no pollution of the character referred to is taking place at the present time, what preventative measures would, in its judgement, be the most practicable to ensure that such pollution does not occur in the future and what would be the most probable cost?

The Reference also stated that the Governments would welcome the recommendations of the Commission with respect to the general and specific water quality objectives that should be established for these lakes, and the programs and measures that are required in the two countries in order to achieve and maintain these water quality objectives.

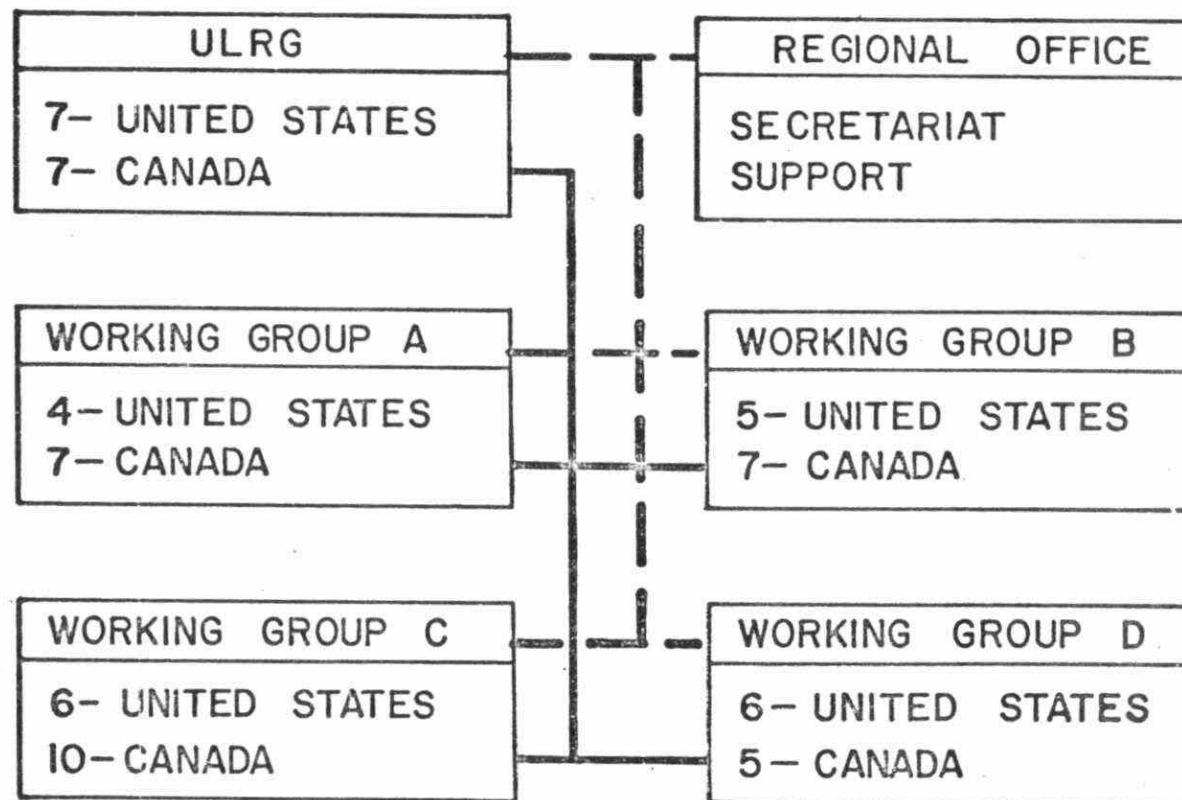
The Reference further requested that the Commission should utilize the services of the international board structure. Illustration #2 shows the relationship of the Upper Lakes Reference Group to the Great Lakes Water Quality Board and the Commission.

Illustration #6 shows the structure of the Upper Lakes Reference Group and its Working Groups.

The Reference Group held its first meeting on November 28, 1972, and has held eleven meetings since that time. The Working Groups have held numerous meetings, both joint and on a national basis. The Group is composed of fourteen members, seven from the United States and seven from Canada. Dr. Robert W. Zeller, Director, Surveillance and Analysis Division, U.S. Environmental Protection Agency, Region V, is Chairman of the

GREAT LAKES WATER QUALITY AGREEMENT

INTERNATIONAL REFERENCE GROUP ON UPPER LAKES POLLUTION



United States Section and Dr. Robert K. Lane, Chief, Scientific Operations Division, Canada Centre for Inland Waters, is Chairman of the Canadian Section.

Each of the five Upper Lakes States has representation, Ontario has four members, and the Federal Governments of the United States and Canada two and three respectively.

The Reference Group prepared a Study Plan which comprised eight study items as follows:

- I Background Information - hydrology, climate, geology, population, water use, land use
- II Main Lake Surveys
- III Interlake Transport
- IV Relationship between and trends in geographic and water resources characteristics
- V Nearshore and point source studies
- VI Whole lake effects - Interpretation of II data
- VII Peripheral costs of engineering, computers, drafting etc.
- VIII Report Writing

Four Working Groups were formed to develop and complete the various study items. These Working Groups have been active and have completed certain phases of the studies.

In its report of some two hundred pages to the Water Quality Board and the Commission entitled "Program Review and Detailed Study Plan for 1974/75" dated February 1974, the Reference Group provided both a status and a program report.

The background information section of the report has been twenty per cent completed and has been planned for completion prior to the end of the fiscal year 1974/75.

During the fiscal year 1973/74, numerous lake-wide surveys were conducted on Lake Superior to obtain physical, chemical, biological, bacteriological and geological samples. Some analysis has been completed. Winter sampling has been completed on Lake Superior and Lake Huron. An extensive study has been completed of the physical exchange of water between Lake Michigan and Lake Huron. The program for this year (1974/75) includes the completion of the collection of water quality on Georgian Bay and Lake Huron as well as the initiation and completion of the major main lake fisheries program.

Industrial, municipal, atmospheric and tributary loadings data are being collected to determine the sources and characteristics of material input. Progress

is being made on the specifics of the loading and behaviour of materials from the Reserve Mining operations in Western Lake Superior. An initial assessment of the program is underway so as to determine its adequacy.

Liaison with the Land Use Activities Reference Group has been established to ensure maximum contribution without duplication to the study on trends in and relationships between geographic and water resource characteristics.

A number of special nearshore studies of local problems were completed on the Ontario side of Lake Superior. The Saginaw Bay study will be continued as well as those studies on nearshore fisheries on Saginaw Bay, Lake Huron and Lake Superior in accordance with the study plan on coastal and local effects.

The study on whole lake effects for the assessment of pollution, the transport of pollutants and the establishment of baseline levels against which to measure future changes in lake water quality is 35 per cent complete.

The cost of the Upper Lakes study from the years 1973/74 to 1975/76 during which the report is to be completed is estimated at eleven and one-half (11.5) million dollars. This cost includes both ongoing and new programs. Of the cost to Canada of approximately six and three-quarter (6.75) million dollars, Ontario will spend one and three-quarter (1.75) million. Part of the Ontario's new program costs will be funded by the Canadian Section of the International Joint Commission. Of the cost to the United States of nearly five (5.0) million dollars, the states of Michigan, Wisconsin and Minnesota will share approximately one-half (0.5) million dollars.

Institutions Reporting to Governments

Illustration #7 shows various institutions which report directly to the Governments. These institutions have responsibilities under the Agreement to make recommendations or to work out agreements on various matters.

Dredging Work Group

An International Working Group on the Abatement and Control of Pollution from Dredging Activities was established in consultation with the Parties to undertake a review of existing practices, programs, laws and regulations with the objectives of developing compatible criteria for the characterization of polluted dredged spoil and recommendations for compatible programs governing the disposal of polluted dredged spoil in open waters. Included in the constraints in the Directive is the requirement that the recommendations will cause harmful effects to be minimized.

GREAT LAKES WATER QUALITY AGREEMENT

INSTITUTIONS REPORTING TO GOVERNMENTS

WORKING GROUP ON DREDGING
6- UNITED STATES 6- CANADA

JOINT CONTINGENCY PLAN FOR OIL AND HAZARDOUS MATERIALS
CANADIAN OPERATION UNITED STATES OPERATION

TECHNICAL CONSULTATIVE GROUP ON RADIOACTIVITY
9- CANADA 8- UNITED STATES

OTHER OBLIGATIONS
COMPATIBLE REGULATIONS STUDIES OF POLLUTION FROM SHIPPING SOURCES

The Working Group on Dredging has six Canadian members chaired by Mr. C.K. Hurst, Chief Engineer and Special Advisor, Design and Construction Branch, Department of Public Works, and six United States members chaired by Mr. Albert C. Printz, Jr., Director, Field Operations, Environment Protection Agency.

This group has completed Phase One of a two phase report. Phase One provides an extensive review of background information.

Phase Two is scheduled for completion by April 1975 and will include as its basis the results of twenty-two research projects in Canada and twenty-nine research projects in the United States at an estimated total cost of 3.9 million dollars. Major projects include the construction of an Artificial Island in Mitchell's Bay, Lake St. Clair, by Canada and a study on the Applications of Simulated Ecosystem Modelling to Dredged Material Research by the United States.

Consultative Group on Radioactivity

This Group was established by the Parties to develop a common (Canada-United States) refined objective for radioactivity for the Great Lakes Basin. This Group has been operating as separate committees with formal contact being provided by the Chairman and Secretary of each committee. Progress by this Group has been slow. However, the Radioactivity Work Group which has been constituted by the Water Quality Board has made progress on its investigations which preclude the Consultative Group's responsibility for the development of radioactivity objectives.

Joint Contingency Plan

This plan for joint action by the United States and Canada supplements national, provincial and regional plans of the Parties. It provides for coordinated and integrated response to pollution incidents caused by oil and hazardous materials in the Great Lakes System. The plan has been maintained up to date and has been invoked as required. It has proven that joint action can be successfully implemented.

The United States Coast Guard and the Ministry of Transport are the responsible United States and Canadian agencies, respectively, with Great Lakes Joint Response Centres located in Cleveland and Toronto.

Other Obligations

The Parties are required to develop compatible regulations (a) for the prevention of discharges of harmful quantities of oil and hazardous polluting substances from ships which includes the related design, construction and operation of vessels, (b) governing the disposal

of vessel wastes by April 15, 1973, (c) for the prevention of discharges of harmful quantities of oil and hazardous polluting substances from onshore and offshore facilities.

The responsibility for coordinating studies of pollution from shipping sources was assigned to the United States Coast Guard and the Canadian Ministry of Transport. These studies include such matters as navigation equipment, traffic routes, traffic control, manning of vessels, aids to navigations systems, waste water, sewage treatment systems, loading and unloading of grain and ore.

The development of compatible regulations for the disposal of vessel wastes has been pursued by all governments, Federal, State and Provincial, without resolution to date.

IMPLEMENTATION OF THE AGREEMENT

During the past few months, considerable publicity has been given to the delays which will prevent programs from being completed or in the process of implementation by December 31, 1975. It is generally understood that "in the process of implementation" means that planning has been completed, funds committed and construction commenced.

Municipal Waste Water Pollution Control

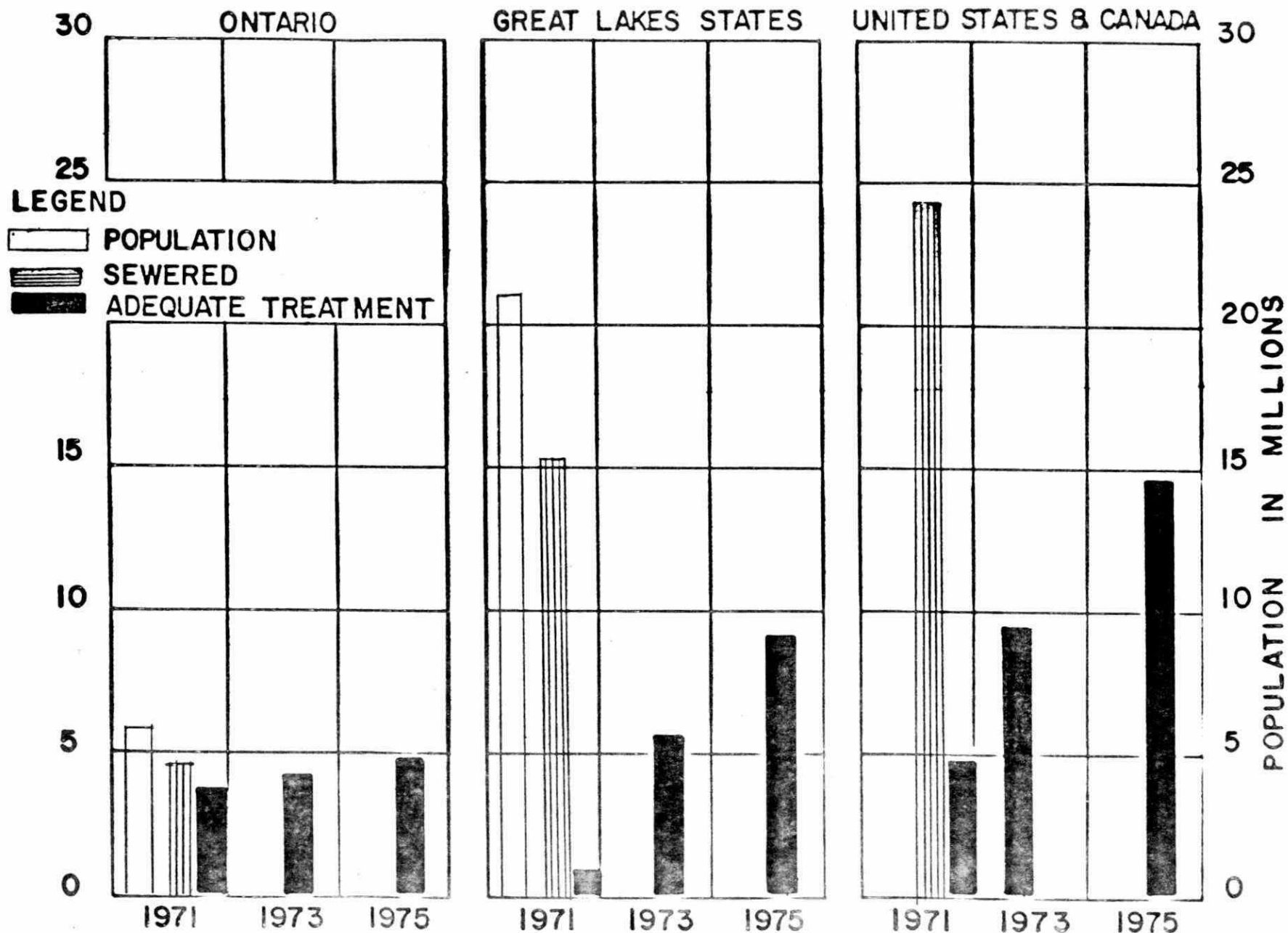
The following table shows the status of treatment facilities basinwide:

<u>TABLE I</u>			
ADEQUATE TREATMENT STATUS			
POPULATION			
	Year	United States	Canada
Adequate Treatment	1971	766,000	3,868,000
	1973 Est.	5,362,000	4,062,000
	1975 Est.	8,900,000	4,739,000
Sewered	1973	15,320,000	4,836,000
Total Basin	1970	*20,800,000	6,300,000

*1970 Basin Population excludes the Illinois Basin Population of 4.6 million

Illustration #8 depicts the relationship between population served with adequate sewage treatment, the sewered population and basin population for Canada, the

POPULATION SERVED BY ADEQUATE SEWAGE TREATMENT-GREAT LAKES BASIN



United States and the total for both Canada and the United States. In that the Canadian portion of the Great Lakes Basin is wholly within Ontario, the population and other statistics pertain to Ontario. The statistics for the United States are aggregate statistics for the eight Great Lakes States.

The population of the Great Lakes Basin as of December 1970 was approximately 31,700,000 with 25,400,000 in the Great Lakes States and 6,300,000 in Ontario. As of December 1973, the sewered population of the Great Lakes States and Ontario was 15,320,000 and 4,836,000 respectively. Between 1960 and 1970 population growth in both the United States and Canadian sections of the Basin approximated ten per cent.

In 1971 nearly four million people were connected to sewage facilities which provided adequate treatment in Ontario whereas in the Great Lakes States approximately three-quarters of a million were similarly connected. Thus, at the commencement of the Great Lakes Water Quality Agreement in April 1972, in the United States the municipal sewage from less than 3% of its Basin population and 5% of the sewered population received adequate treatment, whereas in Ontario 60% of the Basin population and 80% of the sewered population received adequate treatment. By December 31, 1975 it is estimated that 58% of Basin states sewered population will receive adequate treatment and 98% of Ontario's sewered population similarly.

Funding of Municipal Waste Water Systems

In both Canada and the United States, the design development, construction and operation of municipal waste water systems is vested in the municipal level of government. The method for funding the works differs in each country, with the direct tax burden for such works being more visible in Canada at the municipal level. In both countries, the second tier of government, State/Provincial, interface between the municipal and Federal governments. Thus, project plans and fund requests are processed through the State/Provincial levels to the Federal level for the appropriate degree of grant and/or loan, with such funds being processed in the reverse manner to the municipality.

Canada/Ontario

Assistance from the Federal Government for pollution control works has been made available throughout Canada since 1960 through the Central Mortgage and Housing Corporation (C.M.H.C.) under a revision to the National Housing Act. Thereby, long-term financing is provided for sewage treatment and trunk sewers at preferred interest rates for 2/3 of the eligible project value, with forgiveness of 25 per cent of the value of the loan if the project is completed on schedule. The

Canada/Ontario Agreement provides for up to \$167 million of C.M.H.C. funds and \$95 million of Ontario Treasury funds to be allocated on a cash flow basis for the construction of municipal pollution control facilities in the Lower Lakes Basin at both direct and tributary sources over a 5-year period up to December 31, 1975. A similar funding arrangement is being negotiated to assist financing of municipal projects in the Upper Great Lakes Region.

Through the Ministry, Ontario acts as an agent for 30-year, low interest rate financing, construction and operation of sewage treatment facilities.

Area facilities designed to serve more than one municipality are subsidized to the extent of 15 per cent of the capital cost. The Province of Ontario also provides financial assistance for up to 75 per cent of the capital cost of sewage facilities where these costs exceed \$130 per lot. The remaining capital costs are amortized over a period of 40 years. In this scheme of financing, the total capital cost of the system is carried by the Province and the municipality rents the system on a "use" basis.

United States

Under the provisions of Title II of the Federal Water Pollution Control Act as amended October 1972, the Environmental Protection Agency is authorized to make grants to municipalities to assist in the construction of publicly-owned treatment plants. The Federal share is 75 per cent of the eligible cost of the project. Eligible costs now include: sewage collection systems, methods for abating, preventing or reducing storm water and industrial wastes, and wastes in combined storm and sanitary sewer systems. Priority is given to treatment plants and interceptors. Before October 1972 only sewage treatment plants, interceptor sewers and outfall sewers were eligible for construction grant funds.

Section 207 of the amended Act authorized appropriation of funds each year as shown in Table II. The amounts actually released by the Executive Branch of the U.S. Government are also shown.

Litigation has been initiated by Minnesota, Pennsylvania, Wisconsin, Ohio and Illinois to obtain release of the nine billion dollars of the authorized funds which were impounded by the Executive Branch.

TABLE II		
TOTAL U.S. FEDERAL FUNDING UNDER PL 92-500		
	<u>Authorized</u>	<u>Released</u>
FY 1973	\$5 Billion	\$2 Billion
FY 1974	\$6 Billion	\$3 Billion
FY 1975	\$7 Billion	\$4 Billion

The funds are allocated to each state according to a formula that emphasizes state established needs. Each state then distributes funds on a priority system within the state.

In the Great Lakes states, the EPA Administrator adopted a policy to require priority expenditure with the Great Lakes Basin of each state. However, in the 1974 amendments, this procedure was prohibited. States may assign priorities to Great Lakes projects if they wish, but cannot be required to do so. This provision in the law is not expected to change the schedule for construction in the Great Lakes Basin.

Industrial Effluent Pollution Control

Canada/Ontario

At the Federal level, a comprehensive program is underway to develop regulations limiting the discharge of effluents from industrial operations. The regulations are developed under the Fisheries Act and incorporate the principles of best practicable technology for both the treatment of waste waters and the minimization of water use.

To date, three sets of regulations covering the pulp and paper industry, mercury discharges from the chlor-alkali industry and the petroleum refining industry have been promulgated. An additional twenty-seven industries will have federal guidelines and/or regulations governing the limits of effluent discharges permitted by 1978.

The development of these regulations is a cooperative exercise between the Federal and Provincial levels of government as well as the appropriate industrial sector. In the Province of Ontario, the Ministry of the Environment has agreed to adopt the regulations and an arrangement has been worked out whereby the Ministry of Environment is generally responsible for the existing regulations.

The Ontario program for the abatement and control of industrial waste discharges is essentially unchanged since the Agreement was signed in 1972.

United States

The National Pollutant Discharge Elimination System (NPDES) Permit Program, after a slow start in terms of permits issued, is developing into an effective permit program for industrial point source discharges. Early progress was slowed because of the time required for the development of effluent guidelines and permit processing procedures. By the end of 1973, the program

was well underway and by the end of 1974 permits are expected to be issued to all major dischargers.

Permanent authority to operate the permit program was granted to the State of Michigan in October of 1973. Wisconsin and Ohio are expected to obtain this authority within the first few months of 1974; Minnesota, Illinois, Indiana, New York and Pennsylvania should receive authority by late summer of 1974.

In the Great Lakes Basin, 1,456 applications for permits had been received and 108 permits issued as of December 31, 1973.

By Federal law, industrial permits must be issued to all point source dischargers by December 31, 1974. Issuance of a permit means that the industry is in compliance or proceeding on a schedule which will result in attainment of an effluent quality corresponding to that expected from the Best Practicable Technology (BPT) currently available (as defined by the U.S. EPA). Where the effluent quality guidelines by the EPA are not sufficient to meet water quality objectives, the permit system must impose more stringent effluent limitations. Dates for achieving operational levels of effluent quality as defined by the permit program vary for each particular discharge, but compliance can be no later than July 1, 1977. This represents the deadline by which all industrial discharges are to be practicing Best Practicable Technology. Effluent Guidelines defining BPT have been published by the U.S. EPA for twenty-three industries.

Because both the U.S. EPA and the eight states are in the midst of implementing the NPDES permit program, it is not possible to arrive at an adequate estimate of expected delays in individual industrial programs at this time.

Specific reasons for this are the following:

- (1) NPDES Permits have varying compliance schedules, and the only applicable deadline under law is July 1 of 1977.
- (2) Many NPDES Permits to be issued during 1974 are expected to result in litigation, causing indefinite delays.
- (3) Effluent guidelines for several industrial classifications may not be promulgated until the end of 1974. This is resulting in delays to the issuance of certain permits. Also, this means that only an interim baseline (interim guidance) is available from which to judge the adequacy of individual waste discharges.

It should be emphasized that although the majority of permits are expected to be issued in 1974, they will have final compliance dates well beyond December 1975.

Capital Cost Allowances for Pollution Control Facilities

Canada

The Income Tax Regulations amended June 1, 1974 under the Income Tax Act provides for an allowance, in respect of pollution control, of 50% of the capital cost of property acquired primarily for the purpose of preventing, reducing or eliminating pollution of any inland, coastal or boundary waters of Canada.

United States

Section 169 of the Internal Revenue Code, Tax Reform Act of 1969 Public Law 91-172 permits 5-year straight line depreciation of pollution abatement facilities placed in operation on or after January 1, 1969 to abate air or water pollution discharged by plants or properties that were in operation before that date. The Internal Revenue Service also has, in lieu of rapid amortization, a 7% tax credit which is allowed for investment in certain depreciable property.

It must be recognized that the preceding is an extremely simplified version of the tax relief granted through the Income Tax regulations of Canada and the United States; however, the basic comparison are evidenced in the two-year vs. five-year write-off.

CONCLUSIONS

The Great Lakes Water Quality Agreement has provided the foundation for cooperative and coordinated action by the United States and its eight Great Lakes States and Canada and the Province of Ontario. This action, directed toward the maintenance and enhancement of the water quality while ensuring maximum beneficial use of this, the greatest body of fresh water in the world by our and succeeding generations, merits the financial and moral support of all segments of our society. Without this support there can be no assurance that the Great Lakes will provide in the future the sport and commercial fishery, recreational waters, clean water for industry and, most important of all, potable water for the millions of people in the Basin. The monetary cost of prevention is and will be miniscule as compared with the cost of reclamation were the Lakes to continue to degrade with the apparent rapidity of that which pertained to Lake Erie.

The programs initiated by the governments have resulted in improvements in previously defined problem

areas which reflect ongoing and existing program efforts. The reduction of phosphorus content in detergents in Canada, Indiana, Michigan and New York and the implementation of phosphorus reduction at sewage treatment plants has resulted in phosphorus loadings which are lower than projected targets under the Agreement for the Lower Lakes. Recent reports from Michigan have identified a significant reduction in the mercury content of various species of fish taken from Lakes St. Clair and Michigan.



R. R. PARKER

CHAIRMAN - SESSION 2
MR. R. R. PARKER
REID-CROWTHER & PARTNERS
CONSULTING ENGINEERS
DON MILLS, ONT.

"Design and Operation of a Multi-Stage
System for Treatment of Poultry Plant
Wastewater"

BY

L. S. LOVE

L. S. Love & Associates Limited
Process Consultants
Brampton, Ontario



L. S. LOVE

INTRODUCTION

Sherwood Farms, a division of Robin Hood Multifoods Ltd., operate a chicken processing plant at Dundas, Ontario, where 18,000 birds are processed and ice-packed each day. This plant is located on Highway 8 about five miles from Dundas, too far to be serviced with municipal sewers. Therefore the disposal of process waste water is a problem.

In April of 1972 the Company put into operation a two-stage (biological-chemical) plant to treat this waste water prior to discharge into the receiving stream.

The following paper will briefly review the events leading up to this installation, describe the laboratory treatability study that preceded the plant design, and discuss plant operation and cost data.

BACKGROUND

Prior to 1972 the waste water was treated in a three-stage lagoon system having a total area of 6.7 acres, with the effluent being discharged to Spencer Creek, a small stream having an average flow of 60 cfs, and a dry weather flow of 12 cfs. Therefore, during the summer months the treated waste water from Sherwood Farms constitutes about 2% of the total stream flow.

When first put into operation some ten years ago, the lagoon system was more than adequate. However, as production increased to 18,000 birds per day the degree of treatment became less and less. At these production rates the average BOD₅ of the treated effluent was about 80 mg/l. These results were not acceptable to the Ministry of the Environment (then the OWRC) and early in 1968 the Company were advised that the effluent quality must be improved.

Also in 1968, the Hamilton Region Conservation Authority approved the construction of a recreational area on Spencer Creek about one mile down-stream from the point where Sherwood Farms treated effluent enters the Creek. A large dam was constructed across the Creek and many acres of land were flooded to form a large man-made lake, to be used for all types of outdoor sports including swimming. Needless to say this new development was to have a profound effect on the future of Sherwood Farms and its plans for waste water treatment and disposal.

After a lengthy period of negotiations with both the Ministry of the Environment and the Hamilton Region Conservation Authority, it was agreed that Sherwood Farms could remain at its present site and continue to discharge the treated effluent into Spencer Creek, provided this effluent met the following rather strict water quality criteria :

TABLE NO. 1

Required Effluent Quality for Discharge into Spencer Creek	
	<u>Maximum Value</u>
ph	5.5 - 8.5
BOD ₅ , mg/l	5
Suspended Solids, mg/l	5
Grease and Oil, mg/l	0.1
Phosphorous, mg/l	1.0
Total Coliforms, /100 ml	1,000
Colour, Hazen Units	10
Turbidity, Units	10
Residual Chlorine, mg/l	0.5

SOLUTION

A number of schemes were investigated in a preliminary manner to eliminate discharging the waste water into Spencer Creek. These included a total retention system with spray irrigation during the summer months and also a pipe line that would convey the waste water into Spencer Creek below the site of the new dam.

Dr. Weber, of the University of Guelph, completed an extensive study and concluded that spray irrigation on Company property was not possible. The cost of acquiring additional land made this approach quite expensive. The pipe line solution also proved to be expensive and impractical.

The only solution was to construct a rather sophisticated treatment plant capable of 99+% BOD₅ removal, to meet the Hamilton Region Conservation Authority's requirements.

A. In-Plant Survey :

Early in 1971 a detailed in-plant survey was made to measure the waste water strength and volume. From this it was learned that 100,000 lgal of waste water are generated every 10-hour operating day, having the following characteristics :

TABLE NO. 2

Waste Water Characteristics	
pH	5.9 - 7.2
BOD ₅ , mg/l	700 - 900
COD, mg/l	1,100 - 1,400
Suspended Solids, mg/l	300 - 500
Phosphorus, (as P), mg/l	18
Grease and Oil, mg/l	200 - 260
Total Kjeldahl Nitrogen, mg/l	70 - 120
Total Coliforms, per 100 ml	very high

At first, it was thought that the high phosphorus content was due to detergents, but this proved to be incorrect. The phosphorus is, in fact, part of the waste water.

B. Laboratory Treatability Study :

Because the installation of a treatment plant was the only solution to this problem it was decided that an in-depth laboratory treatability study would be required to establish the design criteria for the various treatment processes.

Biological Treatment :

A continuous flow biological reactor of the type shown in Figure No. 1 was set up in our laboratory and operated for a period of six months on waste water obtained daily from Sherwood Farms. It was felt that sufficient nitrogen and phosphorus would be present to support an extended aeration-type biological system and, therefore, these nutrients were not added. This fact was confirmed later by laboratory data.

During the study a range of biological loading conditions were investigated and in each case the system was operated for four weeks to allow steady state conditions to be reached before collection and evaluation of performance data. It was found that a high degree of BOD₅ removal could be obtained under all loading conditions by operating at a high level of MLVSS in the aeration basin. These corresponded to F/M ratios in the 0.05-0.20 range. This combination produced a flocculent activated sludge which settled well (SVI 70 - 90). At the F/M range below 0.1 only a very small quantity of well stabilized excess sludge was produced.

With the particular type of biological reactor used in this laboratory study it was possible to maintain a high level of MLVSS in the aeration basin because all of the settled sludge from the attached clarifier flowed directly back to the aeration basin, where it was quickly resuspended to become part of the biomass. During the study very little sludge had to be wasted to maintain the biomass at 5,000 - 7,000 mg/l.

The laboratory biological reactor performed well with a minimum of attention. However, it was found necessary to scrape the sloping bottom of the clarifier section once each day to remove deposits of activated sludge that adhered to this inclined surface. Our experience indicates that these sludges will adhere to even the steepest inclined surface and if not removed they will eventually rise to the surface and contaminate the effluent.

The biological reactor was operated to simulate field conditions, therefore it was fed for 10 hours each day for five consecutive days, and over the weekend the feed was cut off. This is in accordance with the production schedule at Sherwood Farms. Under these conditions the MLVSS would build up to about 7,000 mg/l and remain relatively stable. No deliberate sludge wasting was necessary.

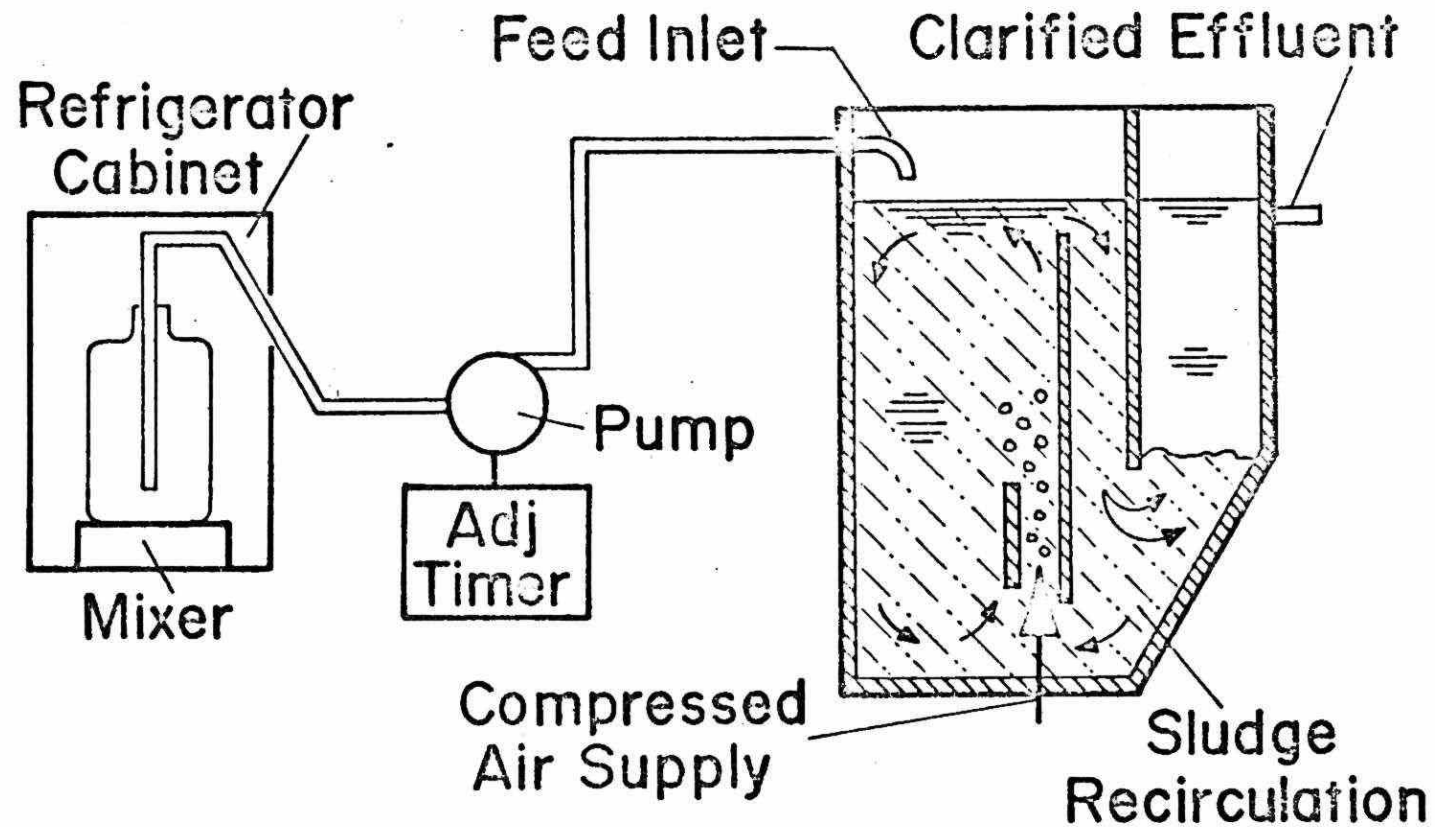


FIGURE 1
SCHEMATIC DIAGRAM
BENCH SCALE TREATMENT PLANT

The effluent from the biological reactor always had a BOD₅ of 15 - 20 mg/l with a filtered BOD₅ of 5 - 6 mg/l. This appeared to be independent of raw waste BOD₅ and also of biological loading. Therefore, it was reasoned that a second stage chemical treatment plant would be able to provide the additional treatment necessary to meet the Hamilton Region Conservation Authority's standards.

Chemical Treatment :

The chemical treatment phase of this laboratory study took the form of a number of standard jar tests conducted on the effluent from the biological reactor. From this study it was learned that a chemical dosage of 50 mg/l of lime followed by 150 mg/l of alum was effective in treating this water. Lime addition was necessary because there was insufficient alkalinity in the waste water to react with the required alum dosage.

In the jar tests 5 minutes were allowed for chemical mixing and 5 minutes of slow stirring for flocculation, followed by 30 minutes settling.

The combined biological-chemical treatment processes produced an effluent with the following characteristics :

TABLE NO. 3

Effluent from Laboratory Treatability Study	
pH	7.5 - 7.8
BOD ₅ , mg/l	3 - 7
COD, mg/l	40
Suspended Solids, mg/l	4 - 5
Grease and Oil, mg/l	< 0.1
Total Kjeldahl Nitrogen, mg/l	5
Phosphorus (P), mg/l	< 1.0
Colour, Hazen Units	5
Turbidity, Units	5

Therefore it was accepted that the desired degree of treatment could be achieved using a biological process followed by chemical treatment.

TREATMENT PLANT DESIGN

It now became necessary to convert the laboratory data into a treatment plant designed for an initial flow of 100,000 Igal per 10 hour operating day during which up to 18,000 birds are processed. Plant design should provide for ready expansion to future capacity of 150,000 Igal per 10 hour operating day while the production rate is nearly doubled to 35,000 birds. At this point the Company added one more restriction to the project : The total capital expenditure of the plant for the initial design capacity could not exceed \$200,000.

From the laboratory study the following design parameters were selected for the treatment plant :

TABLE NO. 4

Treatment Plant Initial Design Parameters		
Flow	-	100,000 Igal/10 hr day 5,500 Igal/1,000 birds
Primary Treatment	-	Screening for Removal of Grease and Feathers
Biological Loading	-	810 lb BOD ₅ /day 45 lb BOD ₅ /1,000 birds 15 lb BOD ₅ /1,000 cu.ft./day MLVSS - 5,000 mg/l F/M - 0.05
Aeration	-	25 HP Mechanical Surface Aerator Retention 3 days
Secondary Clarifier	-	Integral with Aeration Basin 400 Igpd/sq.ft.
Chemical Treatment	-	Lime & Alum Addition 5 min. chemical mixing 5 min. flocculation
Chemical Clarifier	-	300 Igpd/sq.ft.
Polishing Filter	-	4 USgpm/sq.ft.
Sludge Wasting	-	to No. 1 lagoon

TABLE NO. 4A

Treatment Plant, Ultimate Design Parameters		
Flow	-	150,000 Igal/10 hr day 4,300 Igal/1,000 birds
Primary	-	Screening for removal of grease and feathers
Biological Loading	-	1,570 lb BOD ₅ /day 45 lb BOD ₅ /1,000 birds 29 lb BOD ₅ /1,000 cu.ft./day MLVSS - 6,000 mg/l F/M - 0.08
Aeration	-	50 HP required Retention - 2 days
Secondary Clarifier	-	Integral with Aeration Basin 600 Igpd/sq.ft.
Chemical Treatment	-	Lime & Alum addition 3 min. chemical mixing Require additional flocculator
Chemical Clarifier	-	Require additional unit.
Polishing Filter	-	6 USgpm/sq.ft.
Sludge Wasting	-	To No. 1 Lagoon.

It was quickly realized that if the budget were to be maintained good use would have to be made of the existing lagoons; however, because they were only 5'0" deep they could not be incorporated directly into the new treatment plant. Also it was learned that a conventional biological system with a separate aeration basin and separate circular clarifier would result in a capital cost of about \$230,000.

It was then found that if the clarifier and aeration basin were combined into a single structure considerable savings would be realized. Also because the settled sludge from the integral clarifier returns directly to the aeration basin all return sludge pumping and control units would be eliminated. The plant would work exactly the same as the laboratory biological reactor except that it would be equipped with a sludge scraping and scum removal mechanism. This was necessary to avoid the problems of activated sludge adhering to the sloping bottom of the clarifier as observed in the laboratory study.

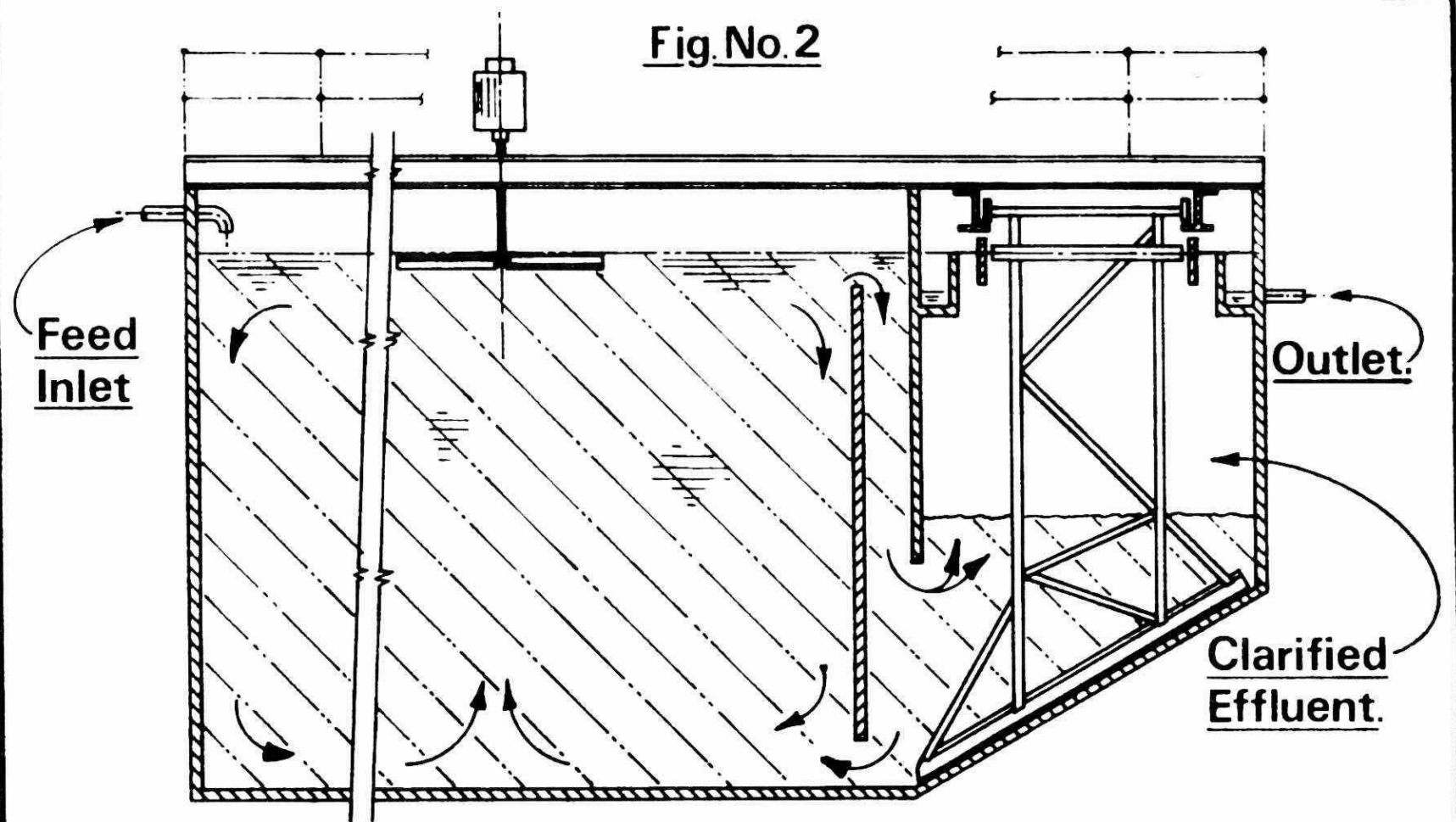
Figure No. 2 shows the aeration basin equipped with the integral clarifier. As the sludge settles in the clarifier it quickly returns to the bottom of the aeration basin where it is re-suspended by the flow pattern created by the Mechanical Surface Aerators. Patents were applied for and have now been granted for this clarifier-aeration basin combination.

While the biological unit was designed to accept the full 100,000 gal of waste water in 10 hours as it flows from the processing plant, the chemical plant was designed to handle this same flow over 24 hours. Thus it was possible to effect a substantial savings in this portion of the treatment plant.

Figure No. 3 shows a general plant of the treatment facility and Figure No. 4 shows a layout of the complete treatment plant, which operates as follows :

1. Waste water from the evisceration room of the chicken processing plant flows over a vibrating screen where most of the grease and remaining feathers are removed.
2. The discharge from the screen flows to a pump well located at the treatment plant where low lift pumps deliver it to the aeration basin.
3. The aeration basin is equipped with a 25 HP Lightnin Mechanical Aerators which supplies sufficient oxygen to maintain a dissolved oxygen content of about 2 mg/l.
4. The mixed liquor in the aeration basin (usually 4,000 - 5,000 mg/l) flows through a set of control gates over a baffle located on one side of the aeration basin down a "chimney" and enters the bottom of the integral clarifier.

Fig. No. 2



TYPICAL CROSS-SECTION
AERATOR & INTEGRAL CLARIFIER.

L. S. LOVE & ASSOCIATES LTD.
BRAMPTON, ONTARIO.

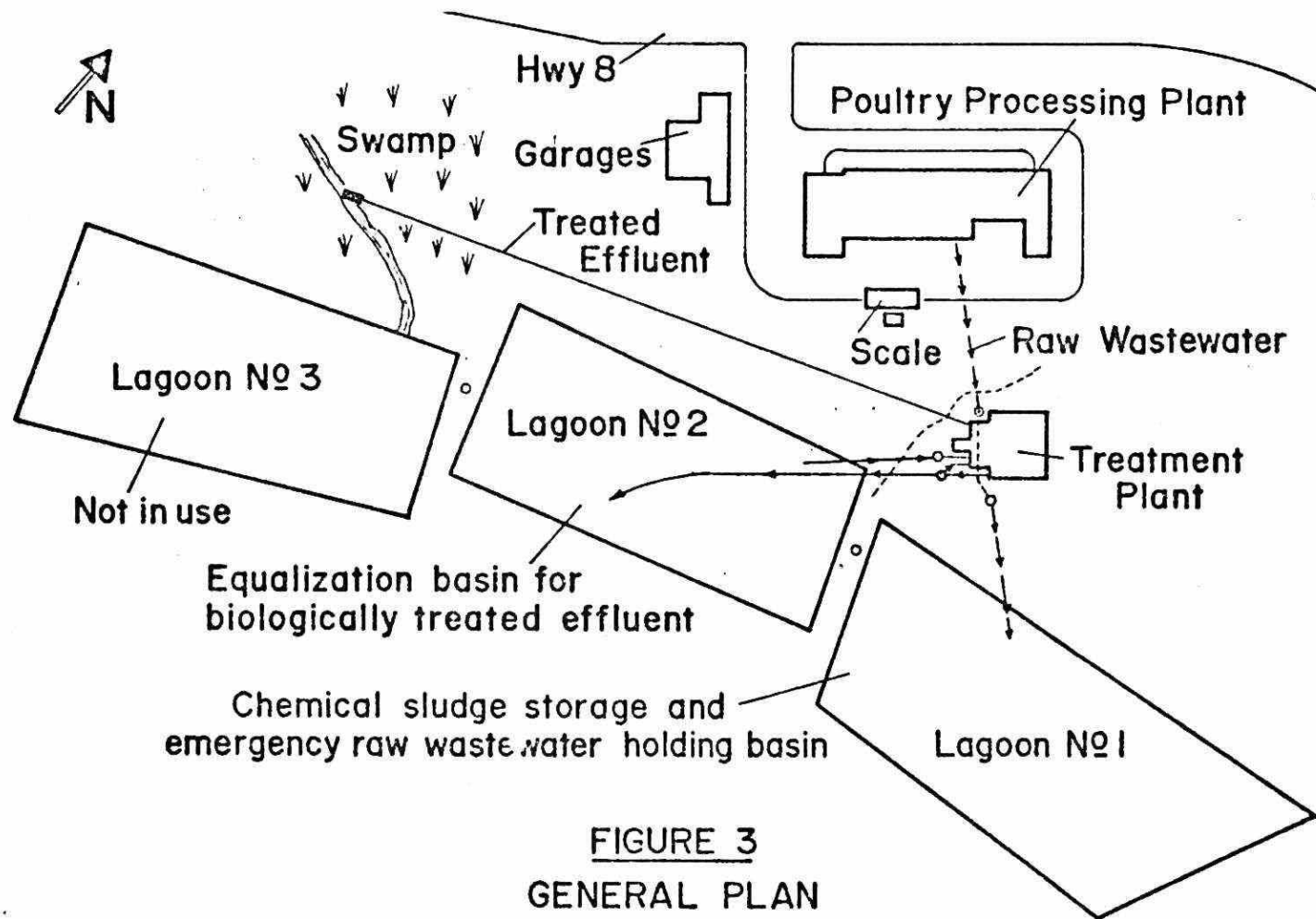


FIGURE 3
GENERAL PLAN

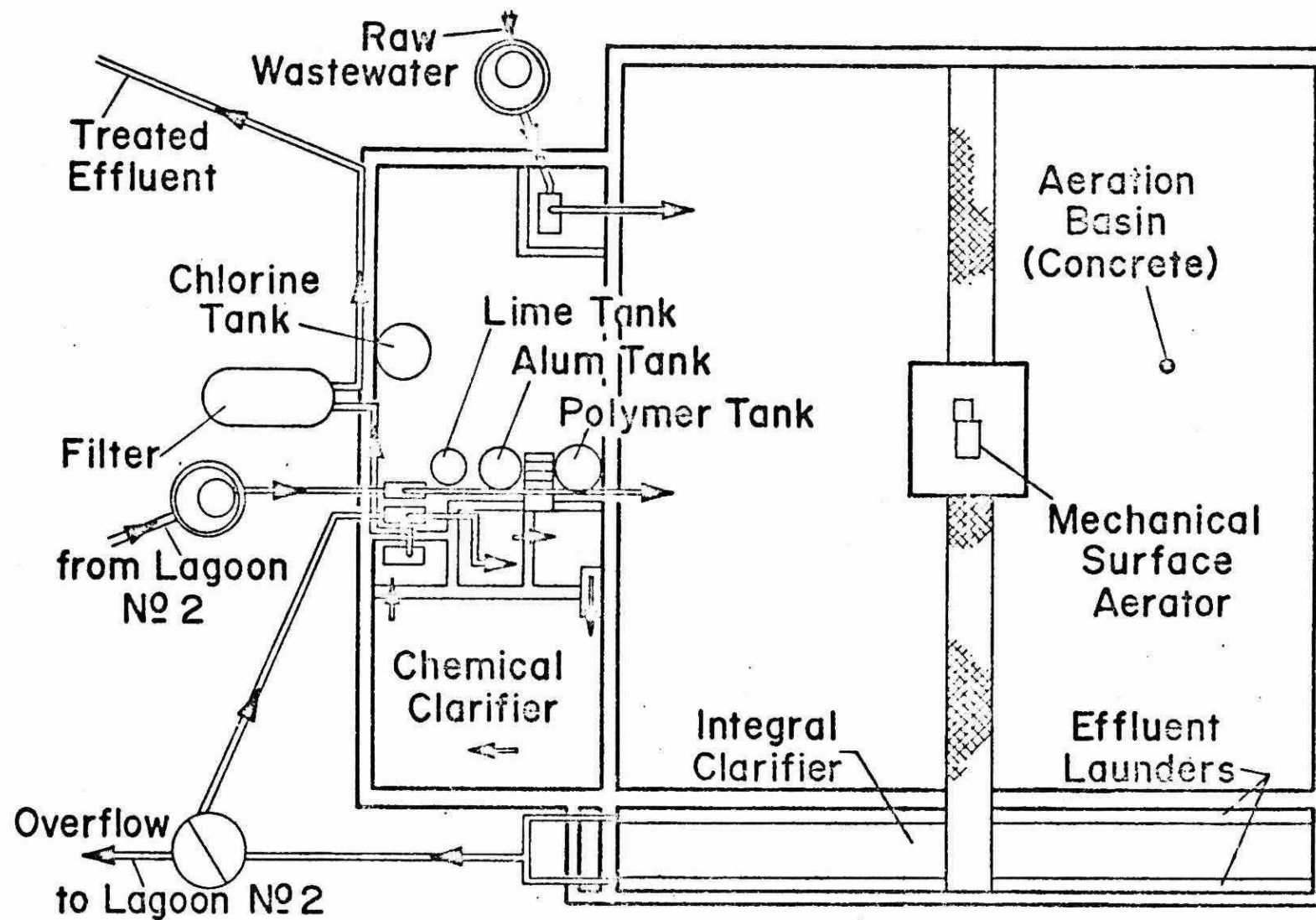


FIGURE 4 TREATMENT PLANT LAYOUT

The control gates permit a large volume to flow down the "chimney" (up to 10 Q). Of this about 9Q is recycled back to the aeration basin along with the settled activated sludge, while Q rises through the integral clarifier and is collected in the launder system as the biological effluent.

5. The scraping mechanism dislodges any activated sludge that may adhere to the sloping clarifier bottom and directs it to the aeration basin, where it is resuspended and becomes a part of the biomass.

The scum is continually skimmed off the clarifier surface into a scum storage box, from which it is removed at regular intervals.

6. The biologically treated effluent flows into a manhole which acts as a "splitter box".
7. A portion flows to the chemical treatment plant while the remainder overflows into No. 2 lagoon. At the end of each day a pump is turned on which delivers water from No. 2 lagoon back into the biological unit and through the chemical treatment plant and polishing filter for complete treatment.

This approach greatly reduced the size of the chemical treatment plant and resulted in substantial savings in capital cost.

8. The effluent from the biological unit flows into a wet well from which it is pumped into the chemical mix basin. These pumps control the operation of the chemical treatment plant on an on-off basis.

Lime, alum and polyelectrolite are proportioned into the chemical mix basin, which is equipped with a mechanical agitator for complete mixing.

9. The water then overflows into a flocculation basin equipped with a slow speed mechanical flocculator. Here the floc particles grow in size to become readily settleable.
10. The flocculated waste water is distributed across the width of a rectangular clarifier to induce laminar flow along the length of the clarifier. The floc settles to the bottom and this sludge is scraped to a sump at one end, from which it is removed by air lift to No. 1 lagoon.

11. The chemically treated and clarified effluent flows into a wet well where chlorine is added. It is then pumped through a four cell dual media pressure filter, and is post-chlorinated before discharge to Spencer Creek.
12. The compartmentalized filter is completely automatic and is designed so that the effluent from 3 cells is used to backwash the fourth cell. This is done automatically in sequence until all four cells have been backwashed.
13. All excess sludge, including waste activated, chemical and filter backwash, is stored in No. 1 lagoon, which has an estimated capacity of 5 - 10 years. At the end of this period the sludge will be spray-irrigated on the Company's property.

TREATMENT PLANT - CONSTRUCTION

Another problem arose before final engineering could begin. Because the integral clarifier had not been used before, the Ministry of the Environment was rather reluctant to issue the required certificate of approval. After much discussion it was agreed that we would build a scale model of the proposed biological plant complete with integral clarifier, and operate it as a biological system in our laboratory for an extended period.

When satisfactory performance of the model plant was demonstrated over a considerable period of time, the Ministry of the Environment issued its certificate of approval in December, 1971.

A contract was awarded to Milverton Millwrights Ltd., in January, 1972, and the treatment plant was ready for start up, on schedule, in April, 1972. Because of the extremely tight construction schedule in many instances the final engineering design was only two weeks ahead of actual construction.

The entire plant was built at a total cost of \$183,000 including engineering fees.

TREATMENT PLANT - OPERATION

During the initial start-up period there was a problem of turbulence in a section of the integral clarifier. This was found to be due to a circular motion in the aeration basin caused by the mechanical aerator. The problem was solved by adding anti-rotational baffles to three sides of the aeration basin.

Some icing problems were experienced with the integral clarifier during the first winter. These normally occurred over the weekends at periods of low or no flow. This problem was solved by placing

plywood sheets over the integral clarifier and blowing warm air from the building into the space between the liquid surface and plywood cover.

No icing problems have been experienced with the Lightning mechanical aerator.

During the summer months we have experienced a problem with sludge removal from the chemical clarifier. The algae present in the sludge cause it to plug the air lifts which deliver the sludge to the No. 1 lagoon. This year we plan to replace the air lifts with a pump which is expected to solve that problem.

Aside from these problems the plant has operated very well for two years with a minimum of operator attention, and continuously produced a high quality effluent for discharge to Spencer Creek. The MLVSS in the aeration basin is generally in the 6,000 - 7,000 mg/l range, and a flocculent activated sludge with good settling properties is produced.

Operating Cost :

A breakdown of the yearly operating costs follows :

1. Operator Time, 4 hr/day	\$ 7,000
2. Chemicals	\$ 3,600
3. Power, 70 HP connected	\$ 4,400

Total yearly operating cost: \$15,000

A major portion of the operator's time is spent manually removing grease from the scum trough. It is planned to automate this operation which hopefully will reduce the operator attention to about \$5,000/year.

After the plant had been operating for six months it was put through the normal 3-week acceptance test as required by the Ministry of the Environment. The data obtained in this test are shown in Table No. 5.

TABLE NO. 5

Comparison of Data on Treatment Plant Performance Sherwood Farms, Dundas, Ontario.		
	Laboratory Study	Treatment Plant Performance
pH	7.5	7.2
BOD ₅ , mg/l	3 - 7	5
COD, mg/l	40	35
Suspended Solids, mg/l	4 - 5	5
Grease & Oil, mg/l	< 0.1	< 0.1
Total Kjeldahl Nitrogen, mg/l	5	< 1.0
Phosphorus, (P), mg/l	< 1.0	< 1.0
Colour, Hazen Units	5	8
Turbidity, Units	5	5
Chlorine Residual, mg/l		< 1.0

These data indicate that the treated effluent met the Hamilton Region Conservation Authority's requirements on all counts.

SUMMARY

It is hoped that some of the information and data contained in this paper will be helpful to others who may be faced with a similar waste treatment problem.

This project was truly a team effort between our Company and the Robin Hood Multifoods Organization. It is for this reason that it has been so successful. We would like to express our sincere thanks and appreciation to the members of the Robin Hood team for their assistance, advice and patience at a time when a lot of work had to be done during a very short period. These gentlemen are :

Mr. Sam Emond	Manager, Sherwood Farms
Mr. Ray Norton	Chief Engineer, Robin Hood Multifoods Ltd.
Mr. Dave Talbot	Project Engineer, Robin Hood Multifoods Ltd.
Mr. Henry O. Arneson	Vice-President, Engineering, Robin Hood Multifoods Inc., Minneapolis

Certainly this paper would not be complete without an expression of appreciation to both the Ministry of the Environment and the Hamilton Region Conservation Authority. In 1968 both government bodies had a real concern about the effect of Sherwood Farms waste water on the Spencer Creek Conservation Area project. All aspects of the problem were thoroughly reviewed and frankly discussed, and by working together in close cooperation a successful solution was found that met the needs of all concerned parties.

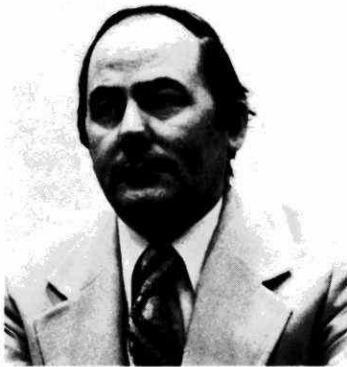
"Solving Environmental Problems
at a Fertilizer Complex"

BY

T. B. LYNCH

Technical Superintendent

Canadian Industries Ltd.,
Lambton Works, Courtright, Ont.



T. B. LYNCH

Canadian Industries Limited has operated a large scale multi-plant fertilizer complex at Courtright, Ontario since the fall of 1966. The central features of the site are its ammonia and phosphoric acid facilities but these are integrated into other units for the manufacture of nitric acid, ammonium nitrate, urea and ammonium phosphates. The Works is the most comprehensive of its type in Canada and its products are sold throughout Eastern Canada, Ohio and Michigan.

The site itself fronts on the St. Clair River, one of the main arteries of the Great Lakes systems. Consequently, because of the Works' size, location, and type of product, there is a high potential for environmental damage. CIL, recognizing this potential, carried out extensive air and water surveys for some eighteen months prior to commencing manufacturing operations and has continued them since that time. Because of this we have been able to measure our impact on what is basically a rural environment. The plants, too, were all designed by their individual

contractors to meet the existing Ontario air and water quality requirement and, in general, the treatments have functioned satisfactorily.

Inevitably, however, a number of pollution control problems did arise involving factors such as treatment inadequacy, exceeding design capacity, and revisions to government regulations. The intent of this paper is to describe ways in which we reacted to a number of these problems.

Ammonia Condensate Treatment

Perhaps the most challenging assignment involved the treatment of ammonia plant condensate. This stream is generated in the shift converter of the ammonia plant at a rate of approximately 200 U.S. g.p.m. Its composition varies with the type of hydrocarbon feedstock to the ammonia plant, as well as the composition and age of the shift catalyst but a typical composition is as follows:

Table I. Typical Analysis of Ammonia Plant Condensate

Ammonia	700 p.p.m.	Methylamine	25 p.p.m.
Methyl Alcohol	1000 p.p.m.	Dimethylene	25 p.p.m.
Carbon Dioxide	2000 p.p.m.	Trimethylamine	25 p.p.m.
Flow	210 g.p.m.	Pressure	300 p.s.g.
Temperature	140° F.		

(Details of the analysis are included in Figure I)

When the ammonia plant began operation, the condensate was directed to one of our gypsum ponds, which was then unused. This was an expediency and, as will become apparent later, could not be used for any significant length of time. Subsequently, two 1400 ft. disposal wells were drilled and, except for some initial problems caused by a number of disused and uncapped oil wells, this system of disposal was followed successfully until the beginning of 1972.

Prior to this, however, it had become obvious that disposal well regulations would inevitably be changed and by 1970 an extensive study had begun to determine alternate means of handling this steam. Three alternatives were considered.

Fig. 1 ANALYSIS OF AMMONIA CONDENSATE

Packing 10% THEED on Fluoropak 80
0.25 x 12 ft. stainless
steel

Oven Temp 130°C

Carrier Gas Helium 90 ml/5 min

Detector F.I.D.

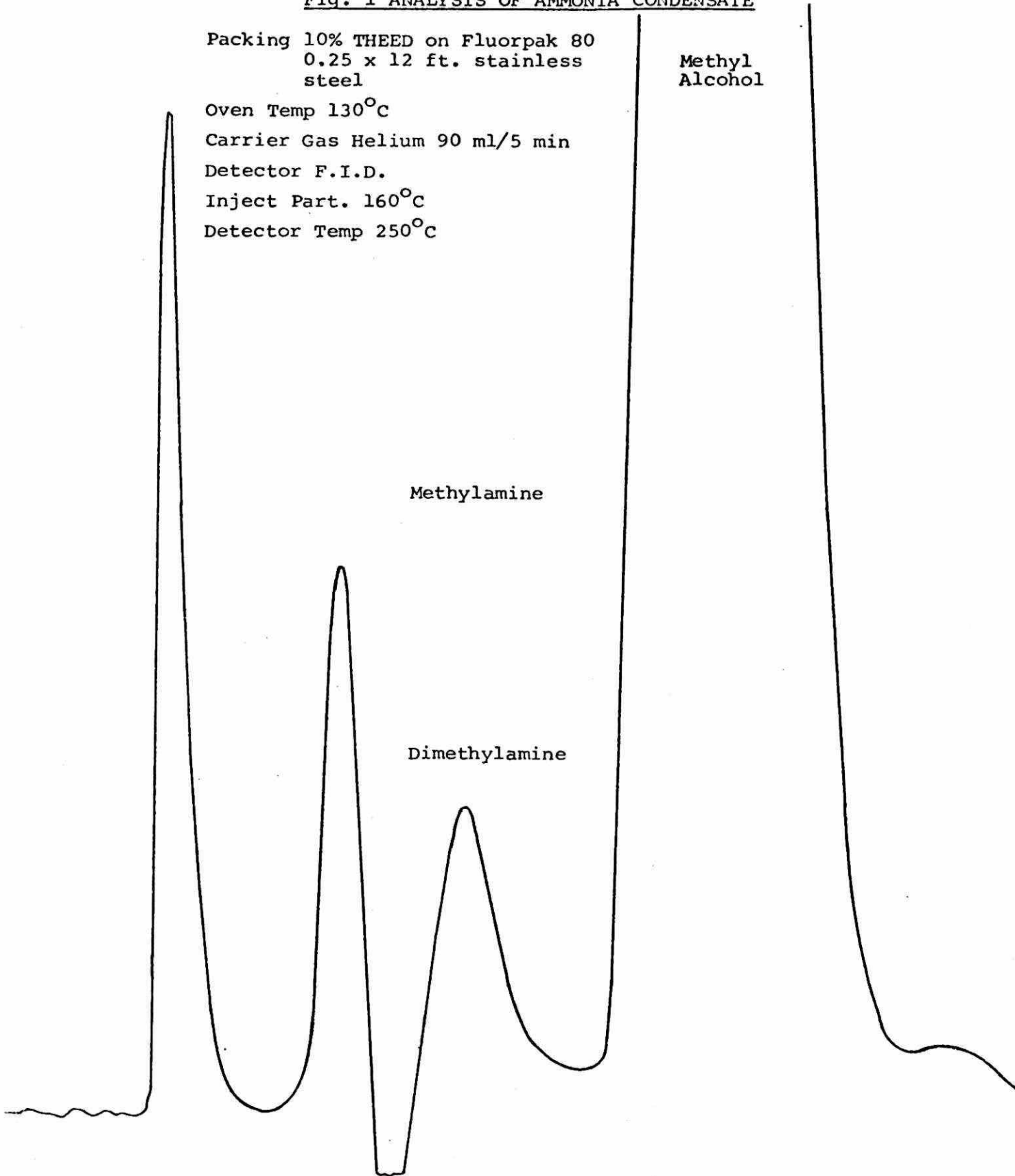
Inject Part. 160°C

Detector Temp 250°C

Methyl
Alcohol

Methylamine

Dimethylamine



- (a) Steam Stripping
- (b) Ion Exchange
- (c) Use of Condensate as Boiler Feed

In practice only (a) and (b) were actively pursued. Alternative (c) formulates a very attractive and intriguing possibility. The problem is, however, that water quality requirements associated with the generation of 1500 p.s.i. steam in the ammonia plant are extremely high, and little is known about the effects and degradation of methanol at these pressures. The inherent risk is that increased foaming at the steam boiler interface could result in impure steam due to carry over of boiler water salts. Laboratory tests on the effects of methanol on the foaming potential of boiler water tend to support this view (Figure 2). Nevertheless, a number of actual plant trials were carried out in England in 1971 in which varying amounts of methanol were added to intermediate pressure boilers. No difficulties were encountered. It appears probable that the methanol is stripped in the de-aerator section of the plant, which would explain the difference between the laboratory and plant results. Further work on the use of condensate in boiler water could obviously prove beneficial.

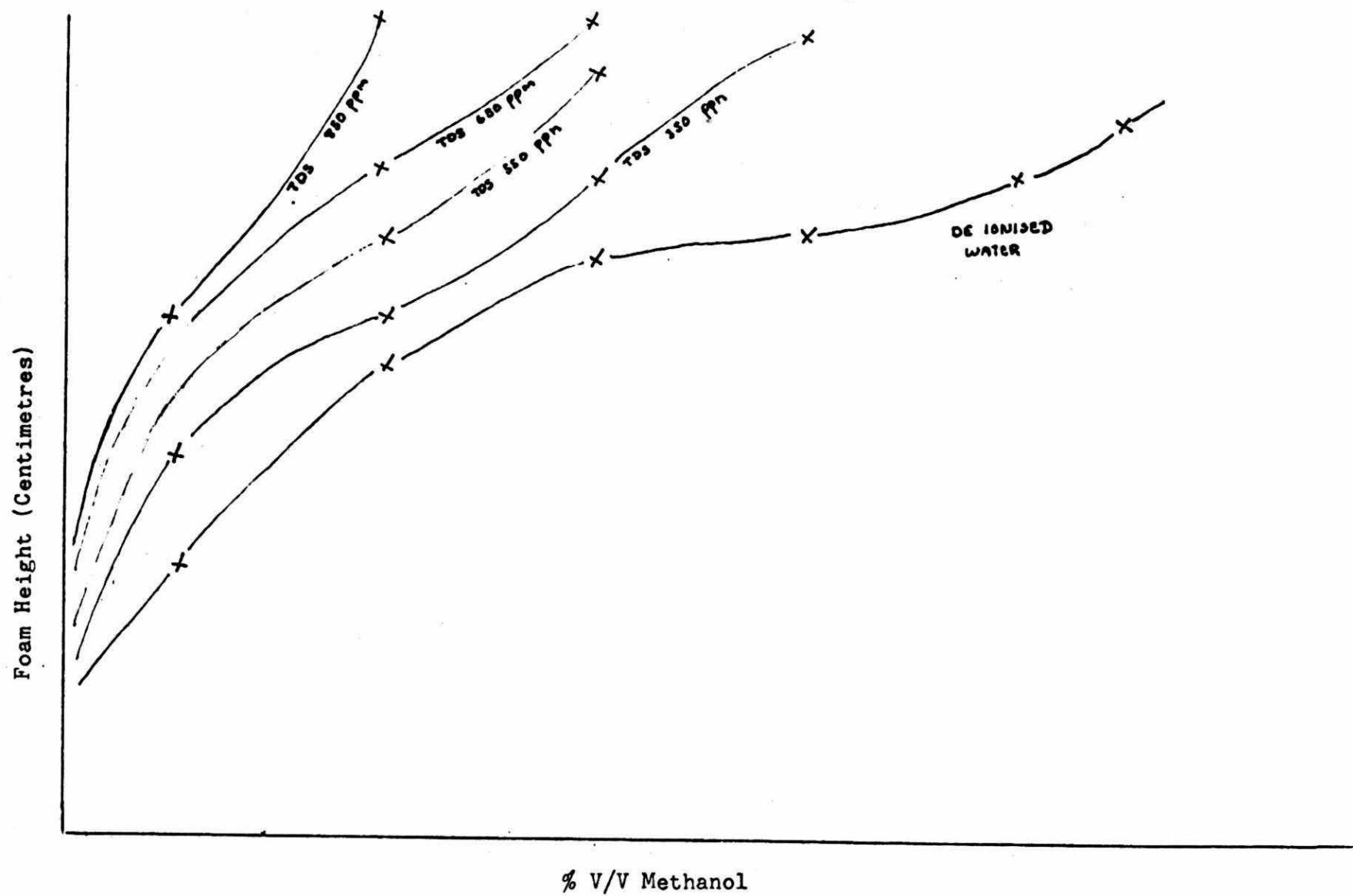
Steam stripping (the second alternative considered) is, of course, already widely used to remove ammonia from waste water. One such unit actually used to remove ammonia and methanol from ammonia plant condensate is shown in Figure 3. The reported efficiency of this unit is very high, with more than 95% of both components being removed. For our particular circumstances, however, steam stripping suffered from two drawbacks:-

1. High steam costs;
2. The release of the methylamines

The characteristic fishy odour, already a contentious issue in the Sarnia area was quite noticeable in our pilot plant trials and, as a result, our investigations were slanted towards ion exchange technology.

Fig. 2

EFFECT OF METHANOL CONTENT AND TOTAL DISSOLVED SOLIDS ON FOAMING
OF BOILER WATERS



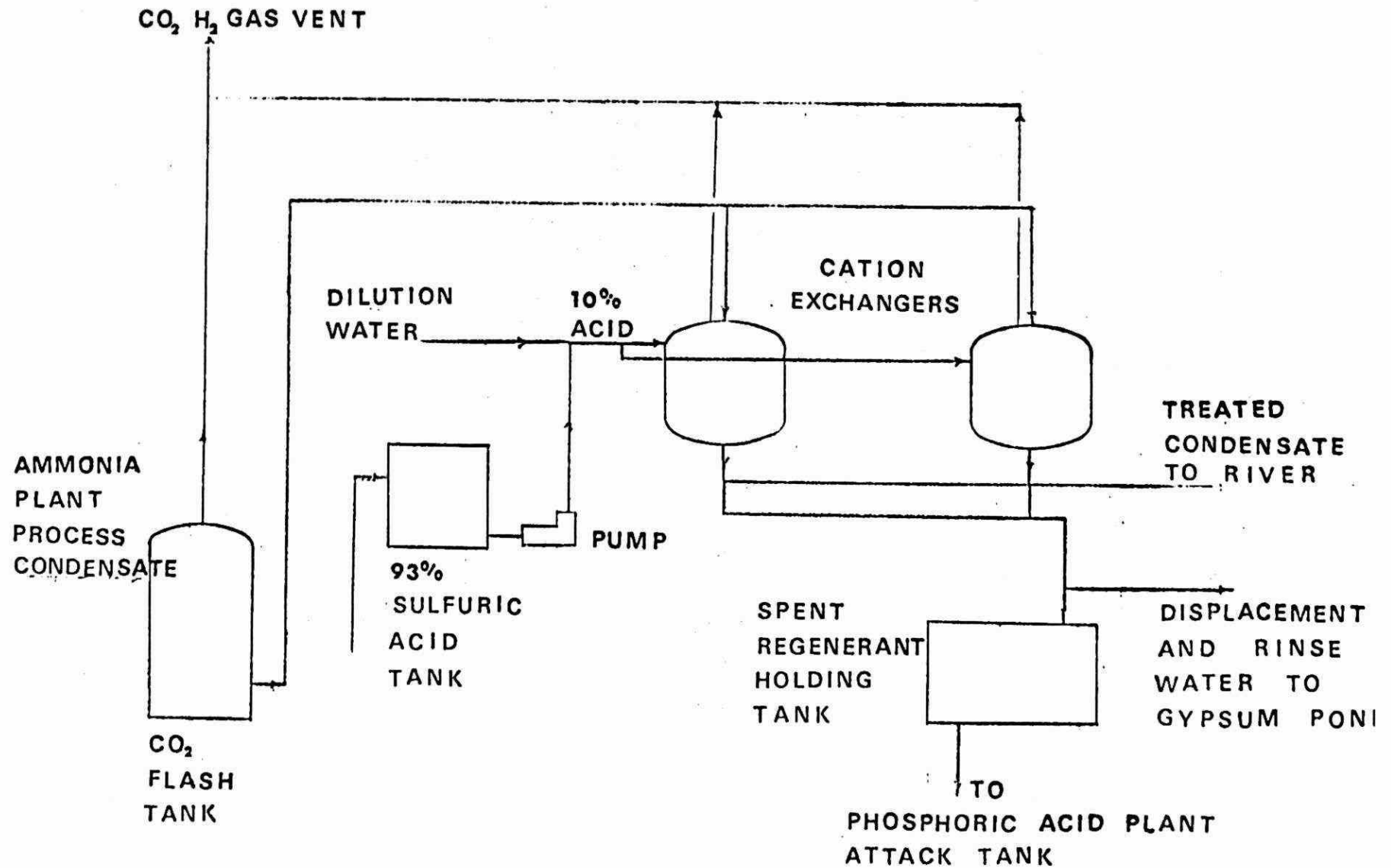
The use of ion exchange to solve the ammonia condensate problem is not new. A number of such units are in operation, the most widely reported being the Farmers Chemical Association's unit at Harrison, Tennessee. This unit utilizes ChemSep technology in which mobile flows of anion and cation resins are continuously charged and regenerated. In the Farmer's Chemical application, strong nitric acid is used as a regenerant, the consequent ammonium nitrate being sold as a component in liquid fertilizers.

By comparison, the CIL unit is quite straightforward. It involves conventional cation exchangers and uses 10% sulphuric acid as regenerant. The ammonium sulphate solution, which results, is transferred to the phosphoric acid plant where it displaces part of the sulphuric acid used in the dissolution of phosphate rock. As the phosphoric acid is subsequently ammoniated to both di and mono-ammonium phosphate, the ammonia from the condensate is eventually recovered as solid fertilizer.

A simplified flow sheet for our ion exchange unit is shown in Figure 4. Its main features are the pressure let down tank and the two rubber-lined ion exchange vessels, each containing several hundred cubic feet of a strong sulphuric acid, ten percent cross-linked resin. This resin was preferred to the carboxylic type because of its higher capacity at the particular pH of our condensate (6 - 7). Note, however, that in plants based on different feedstocks (for example, naphtha) the condensate pH tends to be higher. In this case, a carboxylic acid resin might be preferred. In the actual operation of the unit, condensate pressure is let down in the CO₂ flash drum from a line pressure of 300 p.s.i.g., the flash gases, which consist of CO₂, H₂, and inerts, being vented to the atmosphere. The condensate then flows to the No. 1 exchanger, assuming that this is the one in service, with No. 2 on standby. Ammonium ions are exchanged for hydrogen ions through the resin media, the condensate then flowing from the bottom of the vessel to be discharged into the plant effluent system. The quality of the treated condensate is monitored by a conductivity cell and recorder, which are coupled to an alarm. As soon as the resin capacity is exhausted, the leakage of ammonium ions

Fig. 4

AMMONIA CONDENSATE ION EXCHANGE SYSTEM



increases the conductivity and the condensate is then switched automatically to the second vessel. Simultaneously, the exhausted unit goes into a regeneration mode.

While in the regeneration phase, the resin is first air sparged and backwashed, before being regenerated with 10% sulphuric acid, and subsequently water rinsed. The water used for these various operations is recovered from the discharge of the unit in exchange mode. The effluent from the regeneration step is divided into two, the more concentrated ammonium sulphate being discharged into the phosphoric acid attack tank, and the dilute portion directly to the gypsum ponds. This distinction is necessary because the quantity of water utilized in the phosphate process must be minimized (the reasons for this are explained below).

Analysis of the treated water shows that essentially all of the ammonia and amine compounds are removed by the cation resin. Its conductivity is less than 200 micromhos which is attributed to carbonic acid. The methanol, of course, is relatively unaffected and is responsible for a small increase in B.O.D. in the site outfall - from 2.4 to 3.2. Typical analysis of treated and untreated condensate are tabulated in Table 2

Table 2. Typical Analysis of Treated and Untreated Ammonia Plant Condensate

<u>Component</u>	<u>Untreated</u>	<u>Treated</u>
Ammonia	700 p.p.m.	less than 1 p.p.m.
Methyl Alcohol	1000 p.p.m.	1000 p.m.
Carbon Dioxide	2000 p.p.m.	
Methylamine	25 p.p.m.	less than 1 p.p.m.
Dimethylamine	25 p.p.m.	less than 1 p.p.m.
Trimethylamine	25 p.p.m.	less than 1 p.p.m.
Conductivity		< 200 micromhos

In all, about 95% of both the exchanged ammonia and sulphuric acid regenerant are recovered in the phosphate process. Thus, although the decision to build the ion exchange unit was made independently of potential raw material and savings, these now exceed \$50,000 annually because of recent trends in prices.

Because some salvaged equipment was used in the CIL unit, exact construction costs are not available. Estimates in 1971 indicated that total costs for a completely new unit would approximate \$100,000. Discounting inevitable start-up and design problems, the unit has run without significant problems and with minimal maintenance. Consequently, we are convinced that, for our particular needs, the ion exchange process was the correct choice. It is not uncommon, however, to find at least one "fly in the ointment". In this instance it was simply the addition of water from the ion exchange unit to the gypsum ponds. It aggravated a continuing problem and led to a second series of investigations.

Pond Water Balance

Gypsum ponds are used in the manufacture of wet process phosphoric acid, both as a disposal system for gypsum produced in the phosphate rock - sulphuric acid reaction and also as a total water recycle system. In effect, they eliminate the problem of phosphate in plant effluents. In practice, slightly more than one ton of gypsum is produced for every ton of rock digested (in our case more than 1000 tons/day). After being filtered from the phosphoric acid, the gypsum is slurried with waste water from the plant and pumped to the ponds. The ponds are usually operated in pairs, gypsum settling in the first, from which water decants into the second. The clarified water is then recycled for re-use in the plant. CIL operates two sets of ponds, each set being operated for about twelve months on a rotating basis. Gypsum is removed from the set not in use and used to raise pond walls, before the pond is put back into operation.

As will be appreciated, pond water is grossly contaminated, a typical analysis being as follows:

Table 3. Typical Analysis of Gypsum Pond Water

Phosphate	10,000 p.p.m.	Sulphate	7,300 p.p.m.
Fluorine	3,600	Sodium	1,700 p.p.m.
Silica	2,000	Potassium	300 p.p.m.
Calcium	700 p.p.m.		

Such components prevent its re-use in certain sections of the plant - a fact that results in make-up river water being used in the phosphoric acid process. It follows that, unless water evaporation from the ponds exceeds make-up water plus rainfall, the water balance is disturbed and a water excess accumulates. If allowed to continue, it would necessitate chemical treatment before water could be discharged to the river. The economic cost involved and potential environmental impact of such measures explain our concern about the addition of ion exchange water to the ponds.

Within the phosphoric acid plant itself, the main reaction involves the digestion of phosphate rock with 65% sulphuric acid. For process reasons, the heat load in the digestion system must be carefully controlled and, consequently, before the diluted acid is added it must be cooled. Both the dilution and cooling are carried out in a Karbate tube cooler. If pond water is used, calcium sulphate deposits and plugs the tubes. This necessitates the use of river water and explains the major source of make-up water to the system.

It will be recognized that any potential treatment of pond water must involve the removal of calcium ions before it can be used to dilute sulphuric acid, or at least involve an increase in calcium sulphate solubility. Consequently, and perhaps understandably, our investigations first involved ion exchange. In this instance, we were not successful. Although cation resins were initially effective in removing calcium ions, the resin became fouled and could not be regenerated after two or three cycles. The solution to the pond water re-use problem was eventually solved in our research laboratories. It made use of the fact that when a common ion is added to a solution of a sparingly soluble salt, the latter's solubility is increased. The underlying theory is that as the ionic strength of the solution increases, its activity decreases. Consequently, if the solubility product equilibrium is to be maintained:

$$(C_m + C_{A-}) (f_m + f_A) = \text{constant}$$

a point is reached in the addition of the common ion in which the solubility of CM^+ , the cation, (assuming the added ion is CA^-) will have to increase. In our

case we found that, by increasing the strength of the sulphuric acid to 70% from the normal 65%, we could prevent the deposition of calcium sulphate from the pond water - acid mix. The extra heat load on the digestion unit is insignificant and can be removed with the present equipment. CIL has applied for a patent on this technology, which is now being used effectively to solve our water balance problem. By this means, we have more than compensated for the addition of ion exchange water to the pond system with the added benefit of valuable phosphate recovery. If we could now establish the use of the treated condensate as boiler feed, we would have developed a total recycle system for both pond water and condensate.

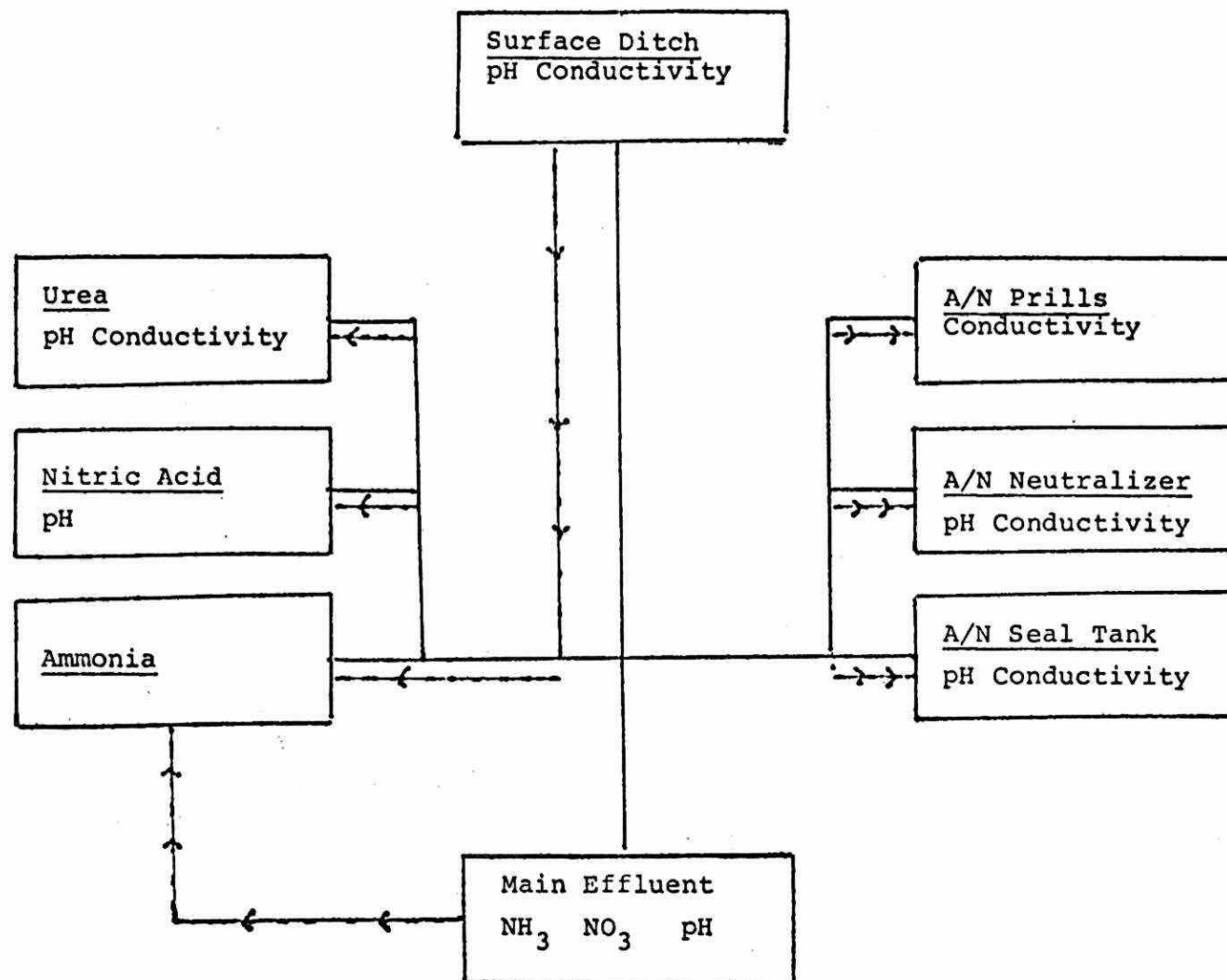
Effluent Monitoring Techniques

In addition to steady state problems just described, plants are inevitably faced by the corresponding occurrences such as process upsets, leaks and spills. It is our experience that the most effective way of reacting to such incidents is by continuous monitoring. As a result we have installed an integrated network of monitoring equipment in our effluent and sewer system. It is designed to alert operating personnel to immediate problems in their plant discharge.

The main aspects of the monitoring network are illustrated in Figure 5. As indicated, the main outfall is monitored by specific chemical analysers, while individual plant sewers are equipped with pH and conductivity equipment. Signals are transmitted to recorders and alarms in individual plants as well as to the ammonia plant control room, which is responsible for co-ordinating the pollution functions on the site.

The main plant effluent equipment consists of a Technicon Auto Analyser which is used to monitor ammonia, a selective ion electrode for nitrate and pH equipment. The instruments are fed from a continuous sample of effluent which is pumped some 200 feet into an analyser building. The sample line is submerged in the effluent stream itself to eliminate insulation problems. Most of the water delivered to the analyser shack is immediately discharged but sidestreams are fed from an overflow device to the various instruments. This ensures continuous representative samples.

Fig. 5. SCHEMATIC OF MONITORING SYSTEM AT CIL'S LAMBTON WORKS



The application of Technicon equipment for effluent monitoring is, by now, standard procedure. In our case, the unit utilizes the indophenol-blue method and is programmed to detect as low as 0.1 p.p.m. ammonia. One channel of the peristaltic pump is used to collect a composite sample which provides data for daily losses, in addition to the unit's instantaneous signal. The selective ion electrode which is used to monitor nitrate is an Orion liquid ion exchange type. Such electrodes can be used without too much difficulty in the laboratory, but in continuous monitoring air bubbles tend to collect beneath the electrode membrane. These short circuit the signal output, causing violent fluctuations on the meter and recorder pens. It was discovered that the air bubbles could be removed as they formed if the electrode was immersed in an upward flow of sample. Reference electrodes used in this application and for general pH monitoring contain a year's supply of potassium chloride crystals, thus eliminating the need for constantly replenishing the usual liquid reservoir. pH electrode assemblies also contain preamplifiers, which are capable of transmitting the signal up to distances of 3 miles on conventional cable without attenuation.

Instrumentation in individual plant sewers includes both pH and conductivity equipment. All the equipment is contained in probes which are submerged in sewers. It is a relatively simple matter for one person to remove this equipment. The pH equipment is equipped with the same innovations described above with the signal being fed directly to recorders in plant control rooms. This eliminates the need to pump samples from the sewer into heated instrument housing. Conductivity equipment is based on carbon rings rather than platinum, thus eliminating the need for periodic replating.

In practice, the presence of chemicals in the sewer and ditch network activates alarms in plant control panels, and alerts the operators to necessary corrective action. The actual contaminant will also be positively identified and quantitatively measured on the main outfall monitors, with the results displayed on the ammonia plant control panel. This information is used by the ammonia board operator to analyze and react to the situation. Before we installed

this equipment, we must admit to certain reservations about operator reaction to such policing. In fact, it stimulated their interest and they reacted enthusiastically. The end result has been a noticeable reduction in incidental losses.

Conclusion

If the past is indicative of the future, it appears inevitable that industry will continue to face changes in pollution control regulations and a tightening of criteria. Based on our own experiences to date, this challenge can be met with innovation and skill which, in addition to solving a social problem, can often result in financial savings to a company. We trust that the information provided in this paper will be of value to others facing similar problems.

"A Progress Report on a Primary Waste
Treatment Clarifier in an Integrated
Kraft and Fine Paper Mill"

BY

Mr. O. Kristiansen
Domtar Fine Papers Ltd., Cornwall, Ont.

and

Mr. J. R. McCallum
Domtar Fine Papers Ltd., Cornwall, Ont.

Dr. L. Behie
Senneville Research Group, Domtar Fine
Papers Limited



O. KRISTIANSEN

INTRODUCTION

During the past 4 or 5 years most pulp and paper mills in Canada have been busy designing and installing clarifiers as primary external treatment to remove suspended solids from the mill effluent.

Effluent standards vary somewhat from province to province and in Ontario the current standard for suspended solids discharged to the receiving water is 50 parts per million. Whether the allowable discharge is expressed as lbs. of suspended solids (OD) per ton of production or, as in Ontario, in parts per million (OD weight of solids in lbs. per million lbs. of effluent), probably does not make much difference in terms of the difficulty of meeting the requirements. It is generally agreed that an allowable loss based on a percentage of production would be the preferable way of expressing the standards because this will not penalize the mill when fresh water consumption is being reduced.

On the other hand, there is a great variation between the type of processes being carried out in the

various mills, thus we have integrated Newsprint and Sulphite Mills, perhaps also with board and coating processes. We have Kraft market pulp mills and integrated pulp and fine paper mills making either Kraft or Sulphite pulp or both along with fine paper. In addition there are usually associated operations such as woodrooms with bark removal, chlorine plants and chlorine dioxide plants. Some sulphite mills even have alcohol and vanillin plants. Other mills buy all of their pulp, i.e. some fine paper mills, and their effluents again are very different from the integrated pulp and paper mills. Some mills are a hundred years old and others are new. The difference in design and the amount of suspended solids lost to the sewers will often make it more difficult for an old mill to achieve the same performance as a new mill. Clarifier performance and efficiency in removal of suspended solids will vary widely according to the nature of the suspended and dissolved solids in the various effluents and depending on the effluent volumes.

Then there are the problems of testing the effluent. How representative is the sample? What type and pore size is the filter paper? As usual, ordinary testing variables come into play, such as persons, methods, errors in drying and weighing. Thus there are a number of variables, and the more complex a mill becomes, the more the nature of the effluent will vary due to spills of various kinds. Before designing a clarifier to handle a given volume of effluent, a number of tests are carried out in the course of a few days to determine the settling characteristics of the suspended solids in the effluent. From the results the required size of clarifier can be calculated for an assumed efficiency. Additional information to assist in sizing the clarifier may be obtained by the use of a pilot plant clarifier, but, again, there may be wide variations in efficiency of suspended solids removal depending on mill conditions. In addition, there is always the problem of scaling up from a pilot plant to full size.

DOMTAR FINE PAPERS LTD., CORNWALL, ONTARIO

In the case of the Cornwall Mill, we had a situation of a complex old mill with numerous extensions

and additions over the years since the start about 1890. (Fig. 1 Mill Layout, Fig. 2 Flow Diagram of Sewer System.) At the time the clarifier design was prepared, there was a Bleached Hardwood Kraft Mill and a bleached sulphite pulp mill, as well as seven paper machines making numerous grades of fine paper and a coating machine making coated boards. In addition, there were 2 woodrooms, one chlorine and one chlorine dioxide plant and a vanillin plant. Total Mill effluent flow peaked close to 60 million Imperial gallons/day.

CLARIFIER DESIGN

1. Preliminary

Tests were carried out by potential suppliers of clarifiers and by mill personnel on effluent properties. Designs to handle the total mill effluent peaking at 60 million I.G./day were worked out. The results indicated that two clarifiers in parallel, each of 220 ft. dia. and 14 ft. side water depth, would be required to meet the standard of 50 ppm suspended solids in the discharge.

2. Simple Static Settling Tests on Mill Effluent

While the early design details of primary clarifiers were in progress, additional tests were carried out on the settling characteristics of the various mill effluent streams prior to mixing in the total mill effluent sewer. Curves showing the concentration of suspended solids about 2 in. below the surface in a 2.5 I.G. container were plotted against time.

The fine paper machine effluents invariably indicated rapid settling. Repeated tests over a period of 3 years have confirmed that the suspended solids concentration in the supernatant liquor will be in the range of 10 - 20 ppm after 5 to 10 mins. settling (Fig. 3 Curve for untreated paper machine effluents.)

The Kraft Mill effluents, however, were quite different, (Fig. 4) and poor settling was obtained, particularly when black liquor or green liquor dregs were present.

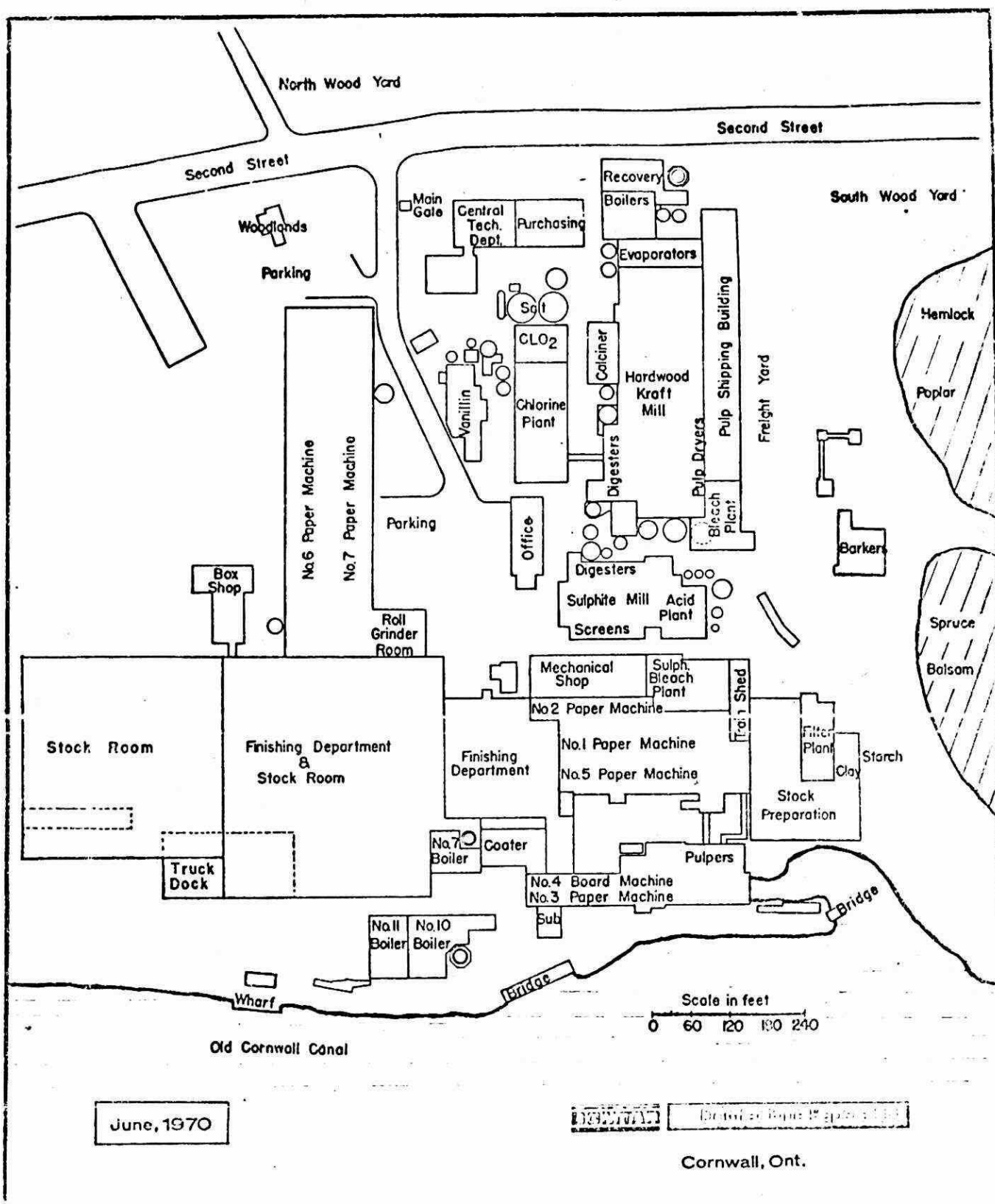


FIGURE 1 MILL LAYOUT - CORNWALL

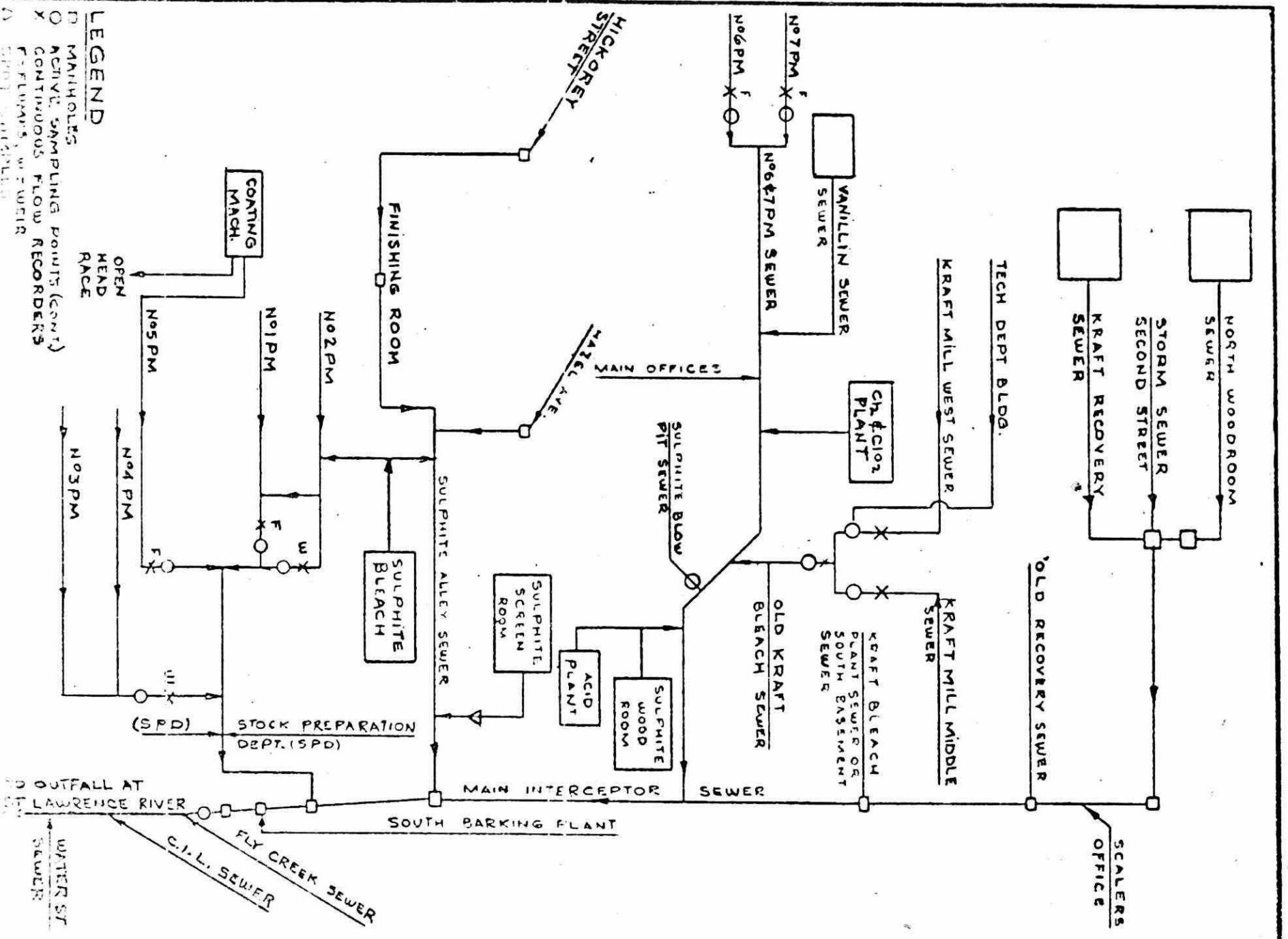


FIGURE 2 FLOW DIAGRAM OF SEWER SYSTEM

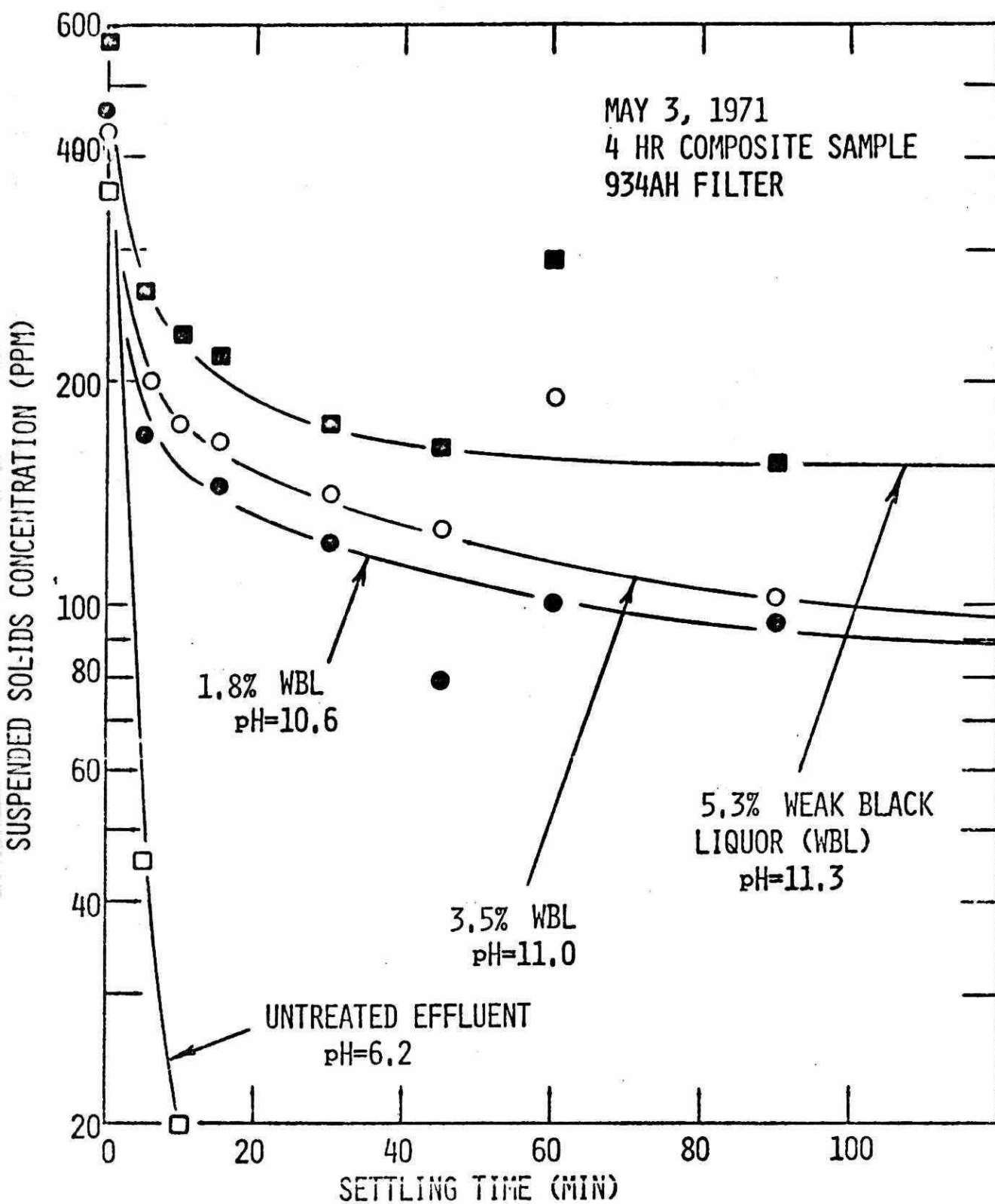


FIGURE 3 EFFECT OF WEAK BLACK LIQUOR (WBL) ON SETTLING OF SUSPENDED SOLIDS IN EFFLUENT FROM NOS 1-5 PAPER MACHINES PLUS STOCK PREPARATION DEWATERANT

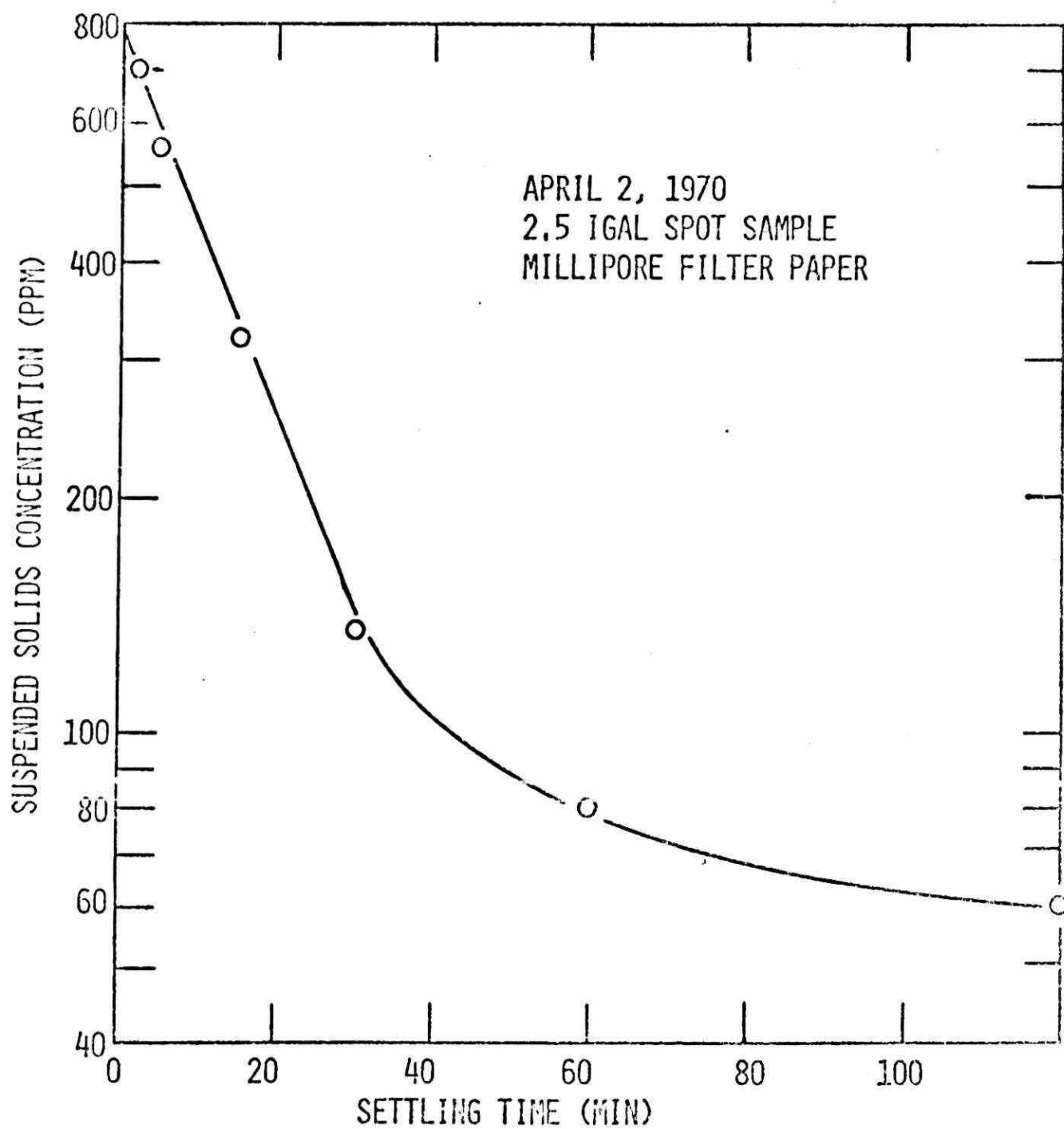


FIGURE 4 STATIC SETTLING TEST ON KRAFT MILL EFFLUENT

Poor settling was also shown by woodroom effluent (Fig. 5). A sample of a settling curve on the combined mill effluent is given in Fig. 6 when the largest woodroom was not operating.

Experiments were carried out by adding a quantity of black liquor or green liquor dregs to paper machine effluent. The contents were well mixed and the supernatant suspended solids measured at five minute intervals. Dramatic reductions in settling rate was obtained as indicated in Figs. 3 and 7. Bleach plant effluents did not seem to have much effect when mixed with paper machine effluents in these tests. Due to their foamy nature it had been expected that they might act similar to black liquor.

Since no beneficial effects were indicated from these test results, it was concluded that green liquor dregs and black liquor spills at least should be prevented from discharging to the clarifier. Plans were accordingly drawn up for a black liquor spill collection system and dewatering and land disposal of green liquor dregs and excess lime mud.

3. Pilot Plant Studies

To assist in determining the requirements of the primary waste treatment plant, a pilot clarifier from Beloit Passavant (Fig. 8) and a pilot coil filter from Komline Sanderson were brought to the mill and installed to enable pilot trials on the total mill effluent. The pilot clarifier ran continuously for more than 30 days. The rise rate was varied over a wide range by adjusting the input flow. Tests were carried out hourly seven days per week. Results varied tremendously as shown in Fig. 9. It appeared that under some conditions the efficiency of suspended solids removal was equally good at 1000 IGPD/ft.² as at 300 and also it was found that at a given rise rate the efficiency of suspended solids removal could be as good at 1000 ppm incoming suspended solids as it was at 250 ppm. The only conclusion possible was that there was a lot of variation in effluent properties and that the initial design of two 220 ft. diameter clarifiers to handle the total mill effluent should

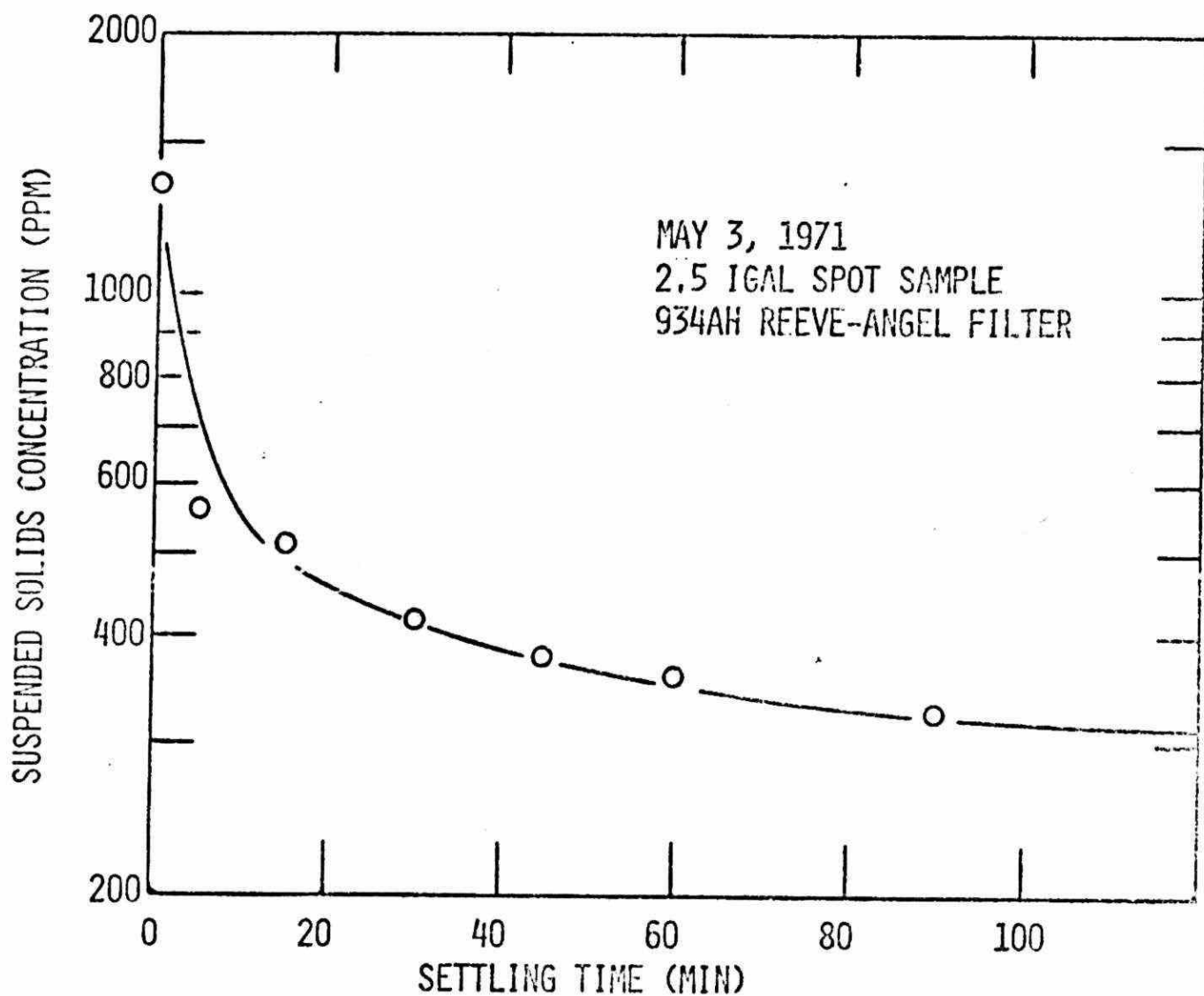


FIGURE 5 STATIC SETTLING TEST ON NORTH WOODROOM EFFLUENT

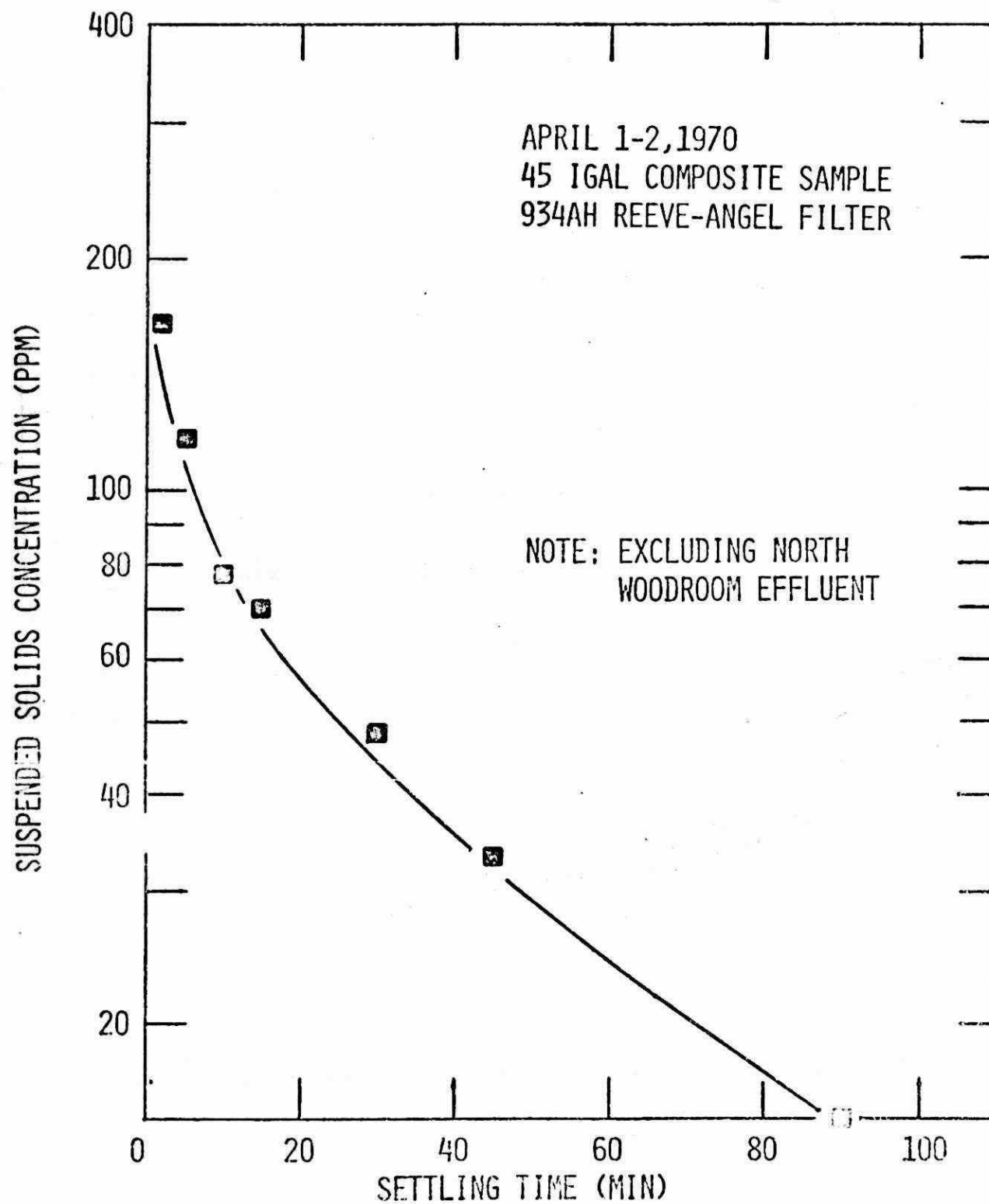


FIGURE 6 STATIC SETTLING TEST ON MAIN MILL EFFLUENT

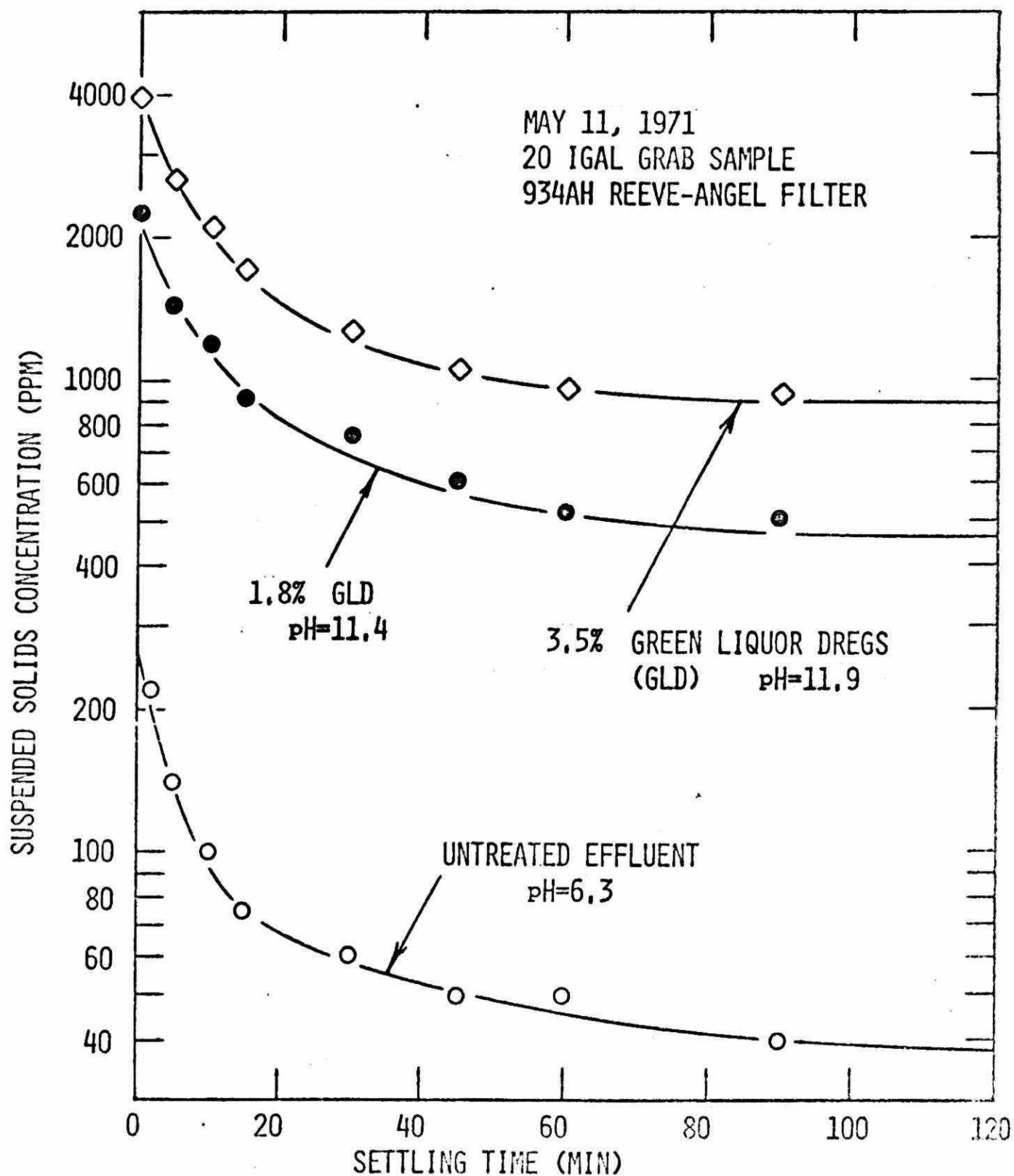
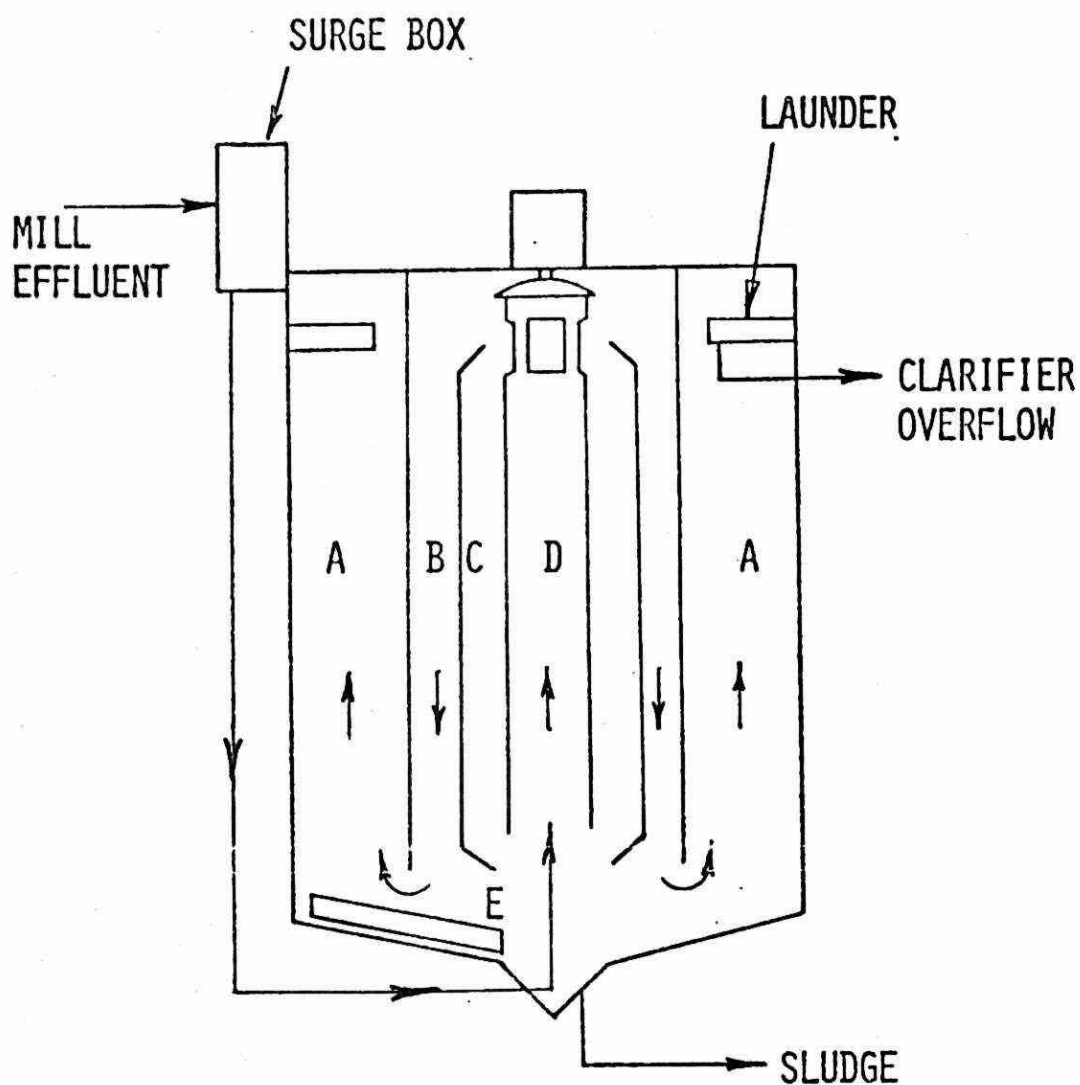


FIGURE 7 EFFECT OF GREEN LIQUOR DREGS (GLD) ON THE SETTLING OF SUSPENDED SOLIDS IN THE MILL EFFLUENT



BELOIT-PASSAVANT KOAGULATOR: HEIGHT = 9 FT
DIAMETER = 6.5 FT

- A - CLARIFIER ZONE (24 FT²)
- B - REACTION ZONE
- C - RECIRCULATION ZONE
- D - INLET ZONE (HOUSES SCREW MIXER)
- E - SLUDGE SCRAPER

FIGURE 8 SCHEMATIC DIAGRAM OF BELOIT-PASSAVANT PILOT CLARIFIER

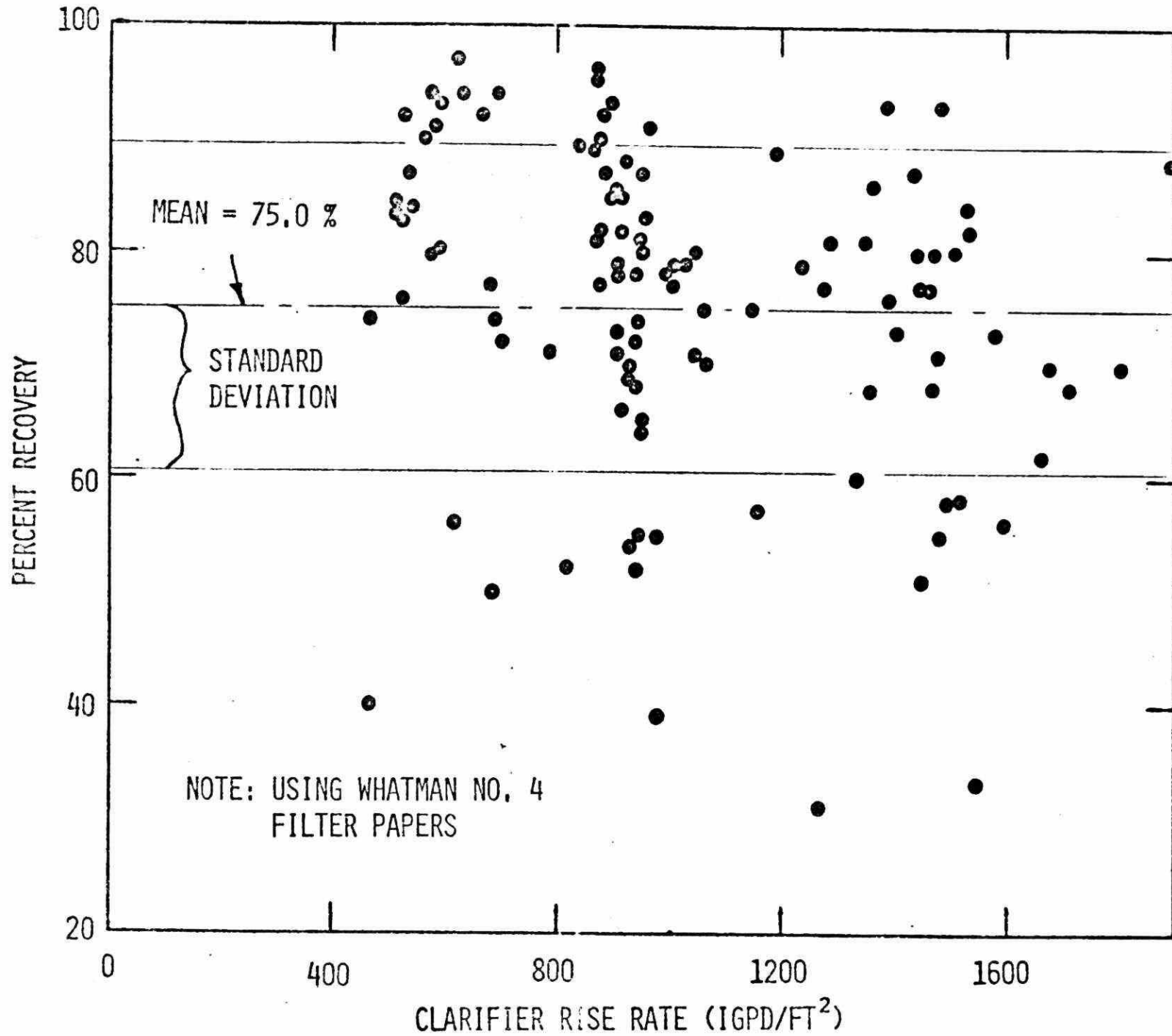


FIGURE 9 PERFORMANCE DATA FOR PILOT CLARIFIER

be reconsidered. Thus, there were indications that there was little or no guarantee that two clarifiers would do the job any better than one single clarifier.

4. Final Design, Cornwall Mill Primary Clarifier System

Based on available information, plans were drawn up to reduce the total mill effluent volume to an average of 34 million IGPD/day by various inplant changes and to design one large clarifier (250 ft. dia.) to handle peak flows of 60 million IGPD. The intention was to evaluate the performance of the single large clarifier and to determine the effect of spill collection systems for black liquor and green liquor dregs as well as to explore the effect of by-passing the Kraft Bleach Plant effluents, prior to deciding whether or not one additional clarifier should be installed.

A few months later, a long pending decision regarding the continued operation of the sulphite mill was made. In May 1972, the sulphite mill, one woodroom and the chlorine and vanillin plants were shut down. The effect of this and the conversion to dry barking in the remaining woodroom reduced the total effluent volume to an average of 34 million Imp. Gals./day and lowered the suspended solids discharge by 40% or 40 T.P.D.

After comparison of the various alternatives of available clarifier systems, it was finally decided to install a 250 ft. diameter 14 ft. side water depth Beloit Passavant clarifier with peripheral drive, centre feed and continuous sludge removal by Wemco centrifugal pumps mounted on the clarifier bridge. A rotary joint at the centre column supporting the clarifier bridge permitted transfer of sludge through 8 in. stainless steel pipes installed inside the centre column and then underneath the clarifier to the adjacent sludge dewatering building. The method of feeding the clarifier was decided in favour of lift pumps, due to poor ground conditions making gravity flow too costly. Three Ingersoll Rand centrifugal vertical lift pumps, each in capacity of 21,600 USGPM, were installed with a combined capacity of

60 million IGPM. Provisions were made to add a fourth pump if this should ever become necessary. Layout of the dewatering building was designed for the possibility of adding another clarifier in parallel. Coarse screens and a Jeffry automatic bar screen and scrapers were installed prior to the sump housing the lift pumps. The dewatering building 105 ft. x 45 ft. x 50 ft. was designed to accommodate an 11 ft. 5 in. diameter by 16 ft. width Komline Sanderson Coil filter and associated equipment such as a Nash Vacuum pump and compressor system for instrument air supply. A centrally located power supply room was provided with clarifier controls and laboratory facilities above it. Provision was made so that a Rietz type V-press could be installed in the future to further dewater the sludge if desirable. Conveyors were installed to transport the sludge discharge from the coil filter to the outside of the building where it could be reclaimed for land disposal. A schematic diagram of clarifier and sludge handling facilities is shown in Fig. 10.

5. Evaluation of Clarifier Performance

While a grit chamber and a 250 ft. single pipe multiport diffuser to handle the total mill effluent volume of 60 million IGPD had already been installed in December 1971, the primary clarifier and dewatering facilities along with additional sewer systems did not become operational until December 1972. Initial problems with the diffuser system due to woodroom waste was eliminated with the start-up of the clarifier, the shutdown of one woodroom and conversion to dry barking. The effect on the St. Lawrence River before and after installation of the submerged diffuser sewer outfall is indicated by aerial photographs in Figs. 11, 12 and 13. Thus, complete elimination of foam on the river was achieved along with excellent dispersion, as evidenced by the disappearance of the discolouration of river water due to improved mixing of the mill effluent with the receiving water.

The clarifier start-up was satisfactory with a few minor mechanical problems with the conveyor system. Blizzard conditions resulted in

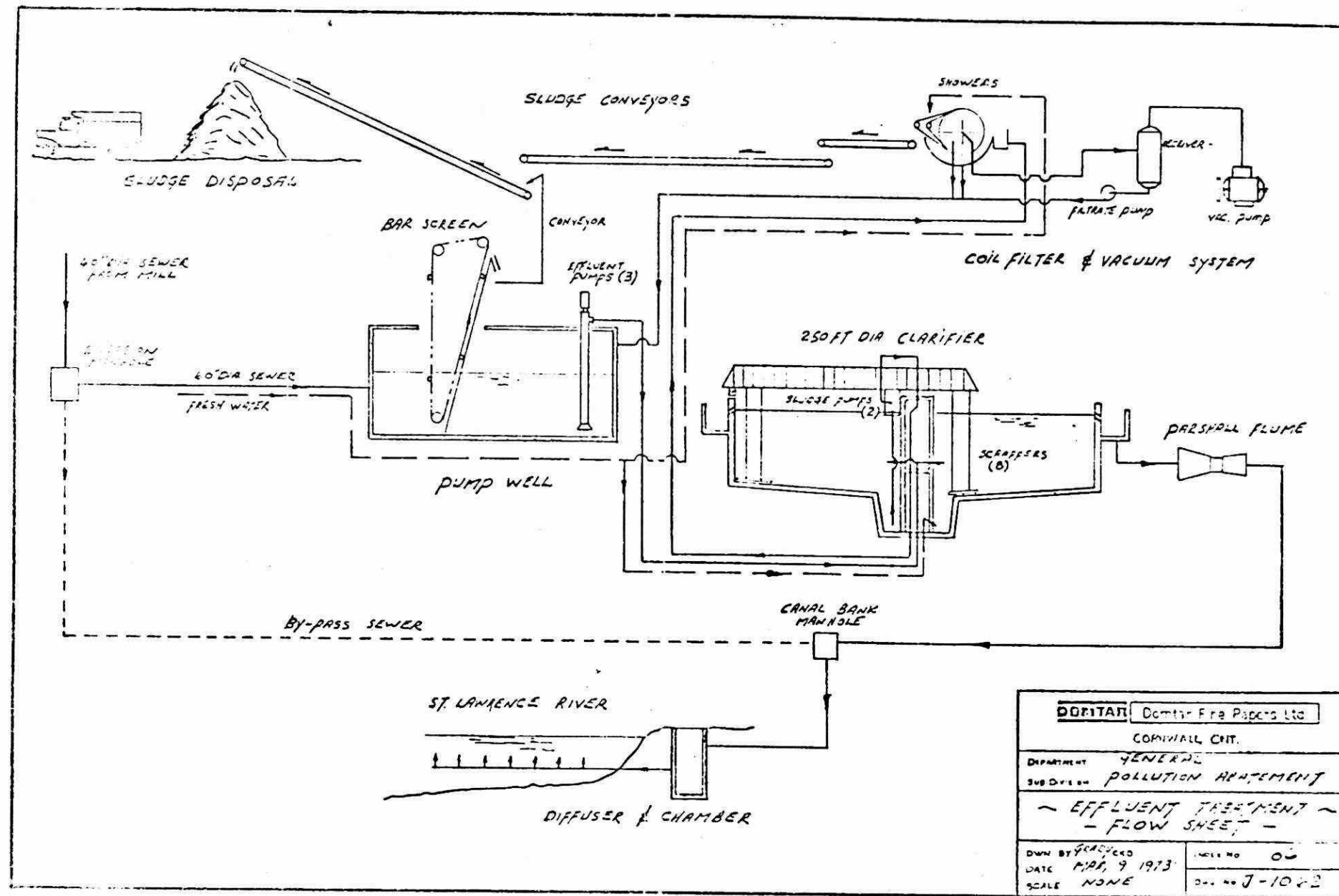


FIGURE 10 SCHEMATIC DIAGRAM OF PRIMARY WASTE TREATMENT SYSTEM

FIGURE 11 VIEW OF MILL SITE AND MILL SEWER OUTFALL AT THE ST. LAWRENCE RIVER PRIOR TO INSTALLATION OF DIFFUSER ON THE RIVER BOTTOM

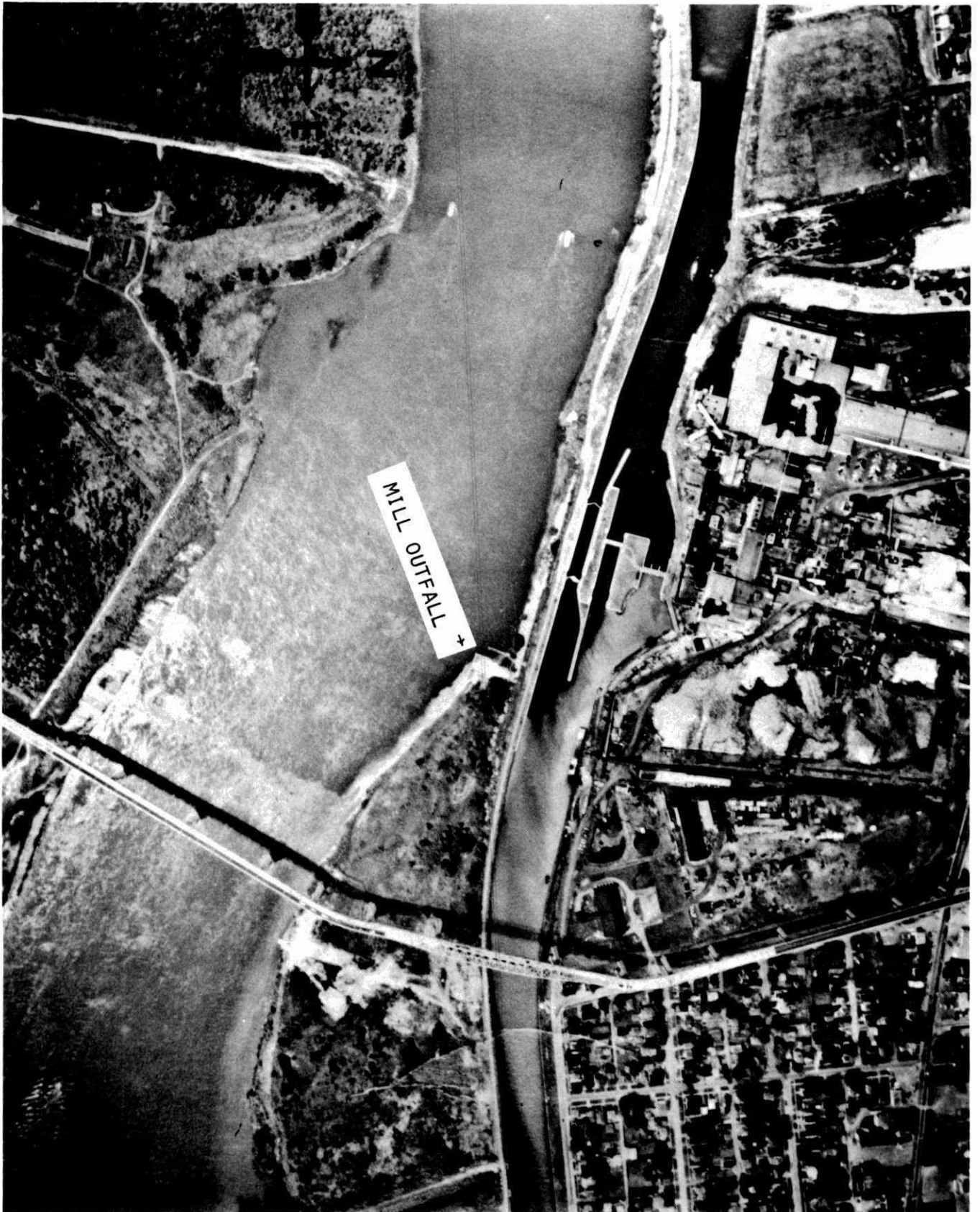


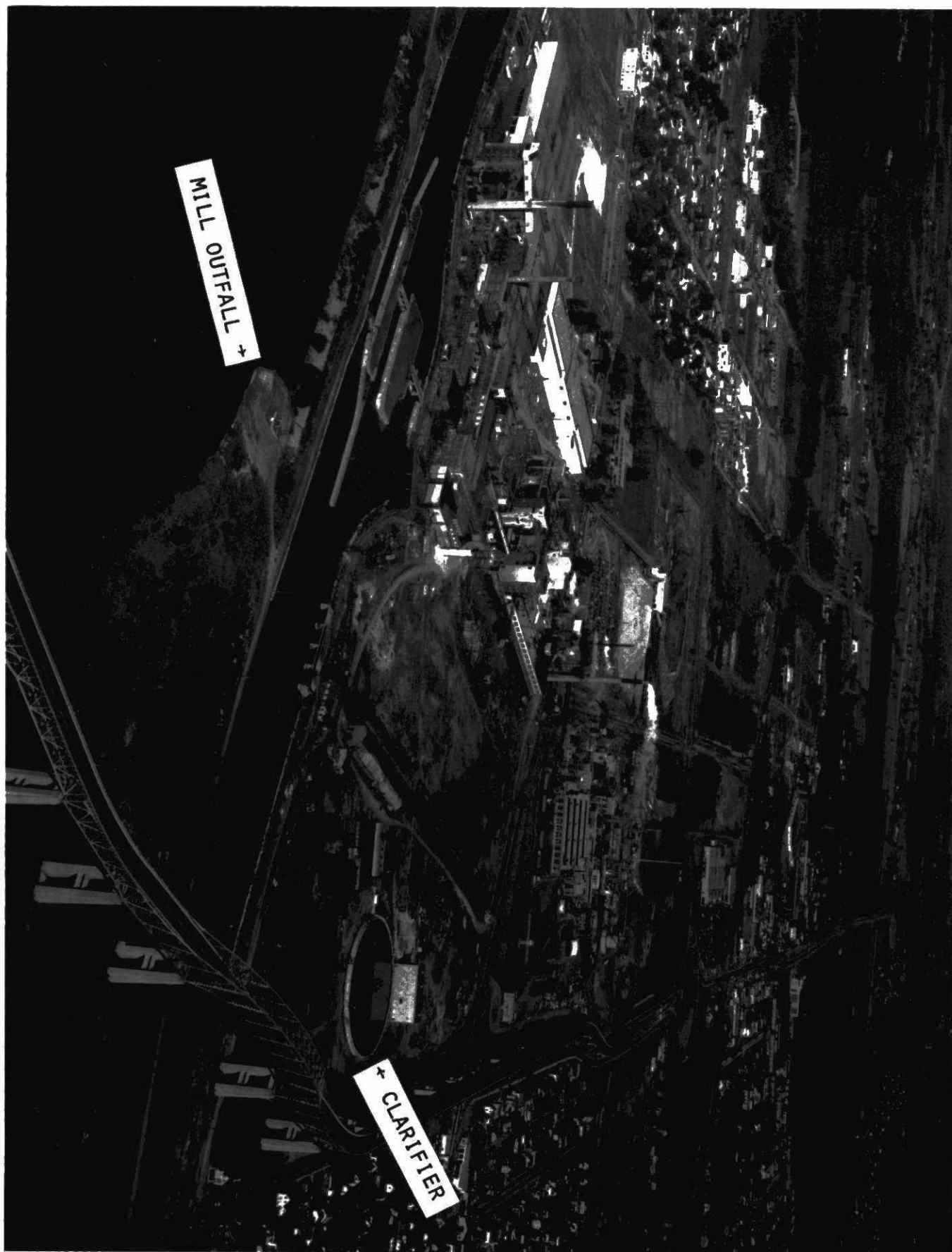
FIGURE 12 PHOTOGRAPH OF FOAM BARRIER AND FOAMING CONDITION THAT EXISTED AT THE MILL OUTFALL PRIOR TO INSTALLATION OF DIFFUSER PIPE

- 63C -



FIGURE 13 APPEARANCE OF ST. LAWRENCE RIVER SHOWING MILL SEWER OUTFALL
AFTER INSTALLATION OF DIFFUSER PIPE AND PRIMARY CLARIFIER

- 630 -



stalling of the clarifier bridge drive a few times when extremely cold weather exceeded the capacity of the electric heating elements buried in the concrete near the rim of the clarifier, resulting in formation of ice on the exposed rim. These problems were restricted to a few shifts during which clarifier operators occasionally had to scrape off ice and apply urea or common salt to assist in preventing ice formation. The Komline Sanderson coil filter was designed to handle 12 lbs. of O.D. sludge per ft.²/hr. although pilot coil filter experiments indicated as high as 25 lbs./ft.² hr. Actual performance has been excellent with peak production at up to 140 (ODT/day) or twice rated capacity. Dry content of sludge cake averaged 25% (OD) based on 1st year results.

The clarifier and sludge removal systems were initially operated 7 days a week, 24 hours per day. A crew of 5 operator/testers had been trained 4 months in advance for this job. Their training included classroom instruction in system design and operation. Training was given in effluent sampling in the various sewer locations and in proper methods for carrying out waste water analysis. Since training proceeded simultaneously with the construction of the primary treatment plant, the operators were given every opportunity to familiarize themselves with all equipment and construction details. A period of 5 days' training was also given at a similar clarifier installation in another mill belonging to Domtar Limited.

The Industrial Waste Division, Ontario Ministry of the Environment, when approving of the clarifier and associated works including spill collection systems for Kraft Mill black liquor, lime and dregs, required that a performance evaluation be undertaken as soon as the clarifier becomes operational, and that the results be reported to that Ministry 4 months after start-up. A detailed test program was set up by the mill prior to the start-up of the clarifier to monitor effluent characteristics before and after the clarifier, including the quantities of sludge disposed to land fill. Spot samples of the clarifier effluent were initially obtained hourly. Duplicate one-litre

samples were taken at each location. The influent was sampled before the bar screen where access and mixing was good. The clarified affluent was sampled in the parshall flume handling the clarified effluent. Turbulence at the point of discharge from the clarifier laundering to the parshall flume assured extremely good mixing and representative samples. Composite automatic samplers designed by the mill were late in being completed, but were in operation during the 2nd quarter of 1973. These samplers were of sturdy design capable of collecting up to 45 Imp. Gals. in an 8 hour shift. They were proportional to flow samplers which could also be operated on manual control of speed. The samplers consisted of a sprocket and chain assembly fitted with a number of receptacles each of 750 ccs. capacity. The heavy duty chain sprockets and caps were of stainless steel as well as the 45 IG sample containers. Scrupulous cleaning with detergent and brushing at the end of a shift was prescribed to eliminate fouling and assist in getting a representative sample. Records were kept of suspended solids concentration determined by Reeve Angel 934AH glass fibre filter, dissolved solids concentration, sludge consistency from the clarifier and after the coil filter, percent ash and calcium carbonate in the clarifier sludge. The daily tonnage of sludge taken out from the clarifier to land fill was closely monitored by the number of truckloads and by weighing 2 or 3 truckloads per day. A typical record sheet is shown in Table 1. From the daily record, an average weekly performance report (Table 2) was prepared and issued to all staff and personnel in the mill that would be particularly concerned, as well as to members of the executive staff of Domtar Fine Papers. From the weekly performance reports the average weekly suspended solids concentration in the clarifier discharge was plotted on a graph.

The results accumulated during the first 3 months showed that the clarifier performance was frequently upset by spills coming from the Kraft Mill and the Paper Mill. The average performance was far from meeting the required standard of 50 ppm suspended solids; in fact, the suspended solids discharge periodically exceeded 200 ppm. Remedial measures were required.

TABLE 1

Domtar Fine Papers Ltd. **DOMTAR**
Papiers fins Domtar Ltée

TABLE 2
TYPICAL WEEKLY PERFORMANCE SHEET CIRCULATED WITHIN DOMTAR

CLARIFIER PERFORMANCE - CORNWALL

DATE	FLOW TO CLARIFIER M.I.E.D.	PH. TO RIVER	% ASH (SLUDGE)	% CaCO ₃ IN ASH	SUSP. SOLIDS P.P.M. TO CLARIFIER	TO RIVER	DISS. SOLIDS P.P.M. TO CLARIFIER	TO RIVER	B.O.D.	C.O.D.	CALCULATED O.D.T. SLUDGE TO LANDFILL PER DAY	REMARKS
SEPT. 9 th					DOWN							
" 10 th	36.5	6.9	22.0	8.8	262	88	698	708	-	-	75.5	KNOTS
" 11 th	37.0	6.9	25.8	6.8	229	72	713	691	-	-	49.2	FOAM
" 12 th	36.0	7.5	23.8	8.8	310	63	711	686	-	-	47.3	
" 13 th	37.0	7.6	26.3	5.3	270	65	714	745	-	-	43.7	LIGHT FOAM.
" 14 th	36.5	7.5	26.5	4.7	229	66	684	654	-	-	37.0	KNOTS.
" 15 th	36.5				DOWN							
AVERAGE	36.6	7.3	24.9	6.9	260	71	704	697				
COIL FILTER PRODUCTION DAILY AVERAGE	5 DAY										50.5	
AVERAGE SLUDGE REMOVAL - DAY	7 DAY										36.1	

SUSP. SOLIDS TO RIVER

MAX. DAILY AVERAGE 88 P.P.M.

AIR " " 63 P.P.M.

DISTRIBUTION: MEMS T.R. HALL, J.R. McCOLLIN, R. PARKIN (S) P. CERASOCCI (S) G.B. STIDWELL, A. LEBANO, J. PISCOPO,

DR. G.H. TOLINSON ATL. OFFICE G. COWHEY (S)

26 HILL TUCK

D.L. R.H. PROCTOR

FILE (3)

6. Improvement of Clarifier Performance

First of all, it appeared that excess turbulence was occurring near the centre column of the clarifier. This resulted in great surges of suspended solids rising to the surface.

These surges of turbulence were observed to be especially noticeable during conditions of effluent contamination with black liquor which also coincided with a foamy effluent. It appeared that the Stengel baffles installed on the outside of the centre column to reduce the velocity of the effluent being discharged into the clarifier were not doing a good job. This was discussed with the suppliers. The mill then decided to experiment and install a deflector of corrugated steel all round the outside of the Stengel baffles, and seal off the upper gap between the metal skirt and the centre column. This modification was done July 1st, 1973. Results were observed for a period of 2 months. While noticeable improvements were obtained, there still seemed to be a substantial release of air bubbles floating suspended solids to the surface directly above the outlet ports from the centre column. It was then decided that this air should be prevented from discharging in this manner by improving the seal above the "skirt" around the centre column and installing a 10 in. vent pipe for each of the 12 outlet ports. This job was done on a one-day clarifier shutdown on September 1st, 1973. These changes materially reduced the turbulence in the clarifier, preventing surges of suspended solids to the surface to a large extent even during foamy effluent conditions. Dynamic response curve shown in Fig. 17 illustrated that the flow pattern in the clarifier approached plug flow with some dispersion. Consequently, there was no serious channelling in the clarifier. While results were encouraging, there was still a long way to go to get down to 50 ppm suspended solids in the clarified effluent.

While black liquor spill collection systems had been installed in the Kraft Mill connecting all black liquor storage tank overflow pipes to a large spill collection tank, the

problem of foamy black liquor contamination persisted at unpredictable intervals. Thus, in March 1973, additional intensive studies were carried out in the Kraft Mill. Two long time employee technicians observed and recorded all possible sources of spills, working 12 hour shifts for 2 weeks.

This survey indicated many shortcomings that had not been solved by the original black liquor spill collection system. More than one dozen projects were established and work proceeded on closing up these sources of spills as fast as possible. By the middle of September 1973 the effect of the various spill collection systems and work done on the clarifier had indicated a steady improvement in reduced suspended solids discharge. The weekly averages were down to 70 ppm and occasional figures of 50 ppm began to occur in the daily averages. However, at this time, the lime mud and dregs spill collection system, that became operational in April 1973, began to suffer frequent breakdowns, resulting in dregs and lime mud being sewerred from time to time. Operational difficulties in the Kraft Mill also resulted in more frequent black liquor contamination of the mill effluent. As a result, the trend of reduced suspended solids discharge was gradually reversed as shown in Fig. 14.

7. Further Studies of Clarifier Performance and Effluent Characteristics

This trend resulted in more intensive testing by the mill waste control group as well as assistance from Domtar Central Research in an all-out effort to determine the causes of the poor clarifier performance and devise effective remedies. The nature of the clarifier influent was studied by Research in order to determine lignin contents by spectroscopic analysis in an attempt to correlate this with suspended solids discharged from the clarifier. Total mill effluent colour and settling characteristics were monitored by the clarifier operators hourly using Imhoff cones and allowing 4 hours settling before noting the volume of

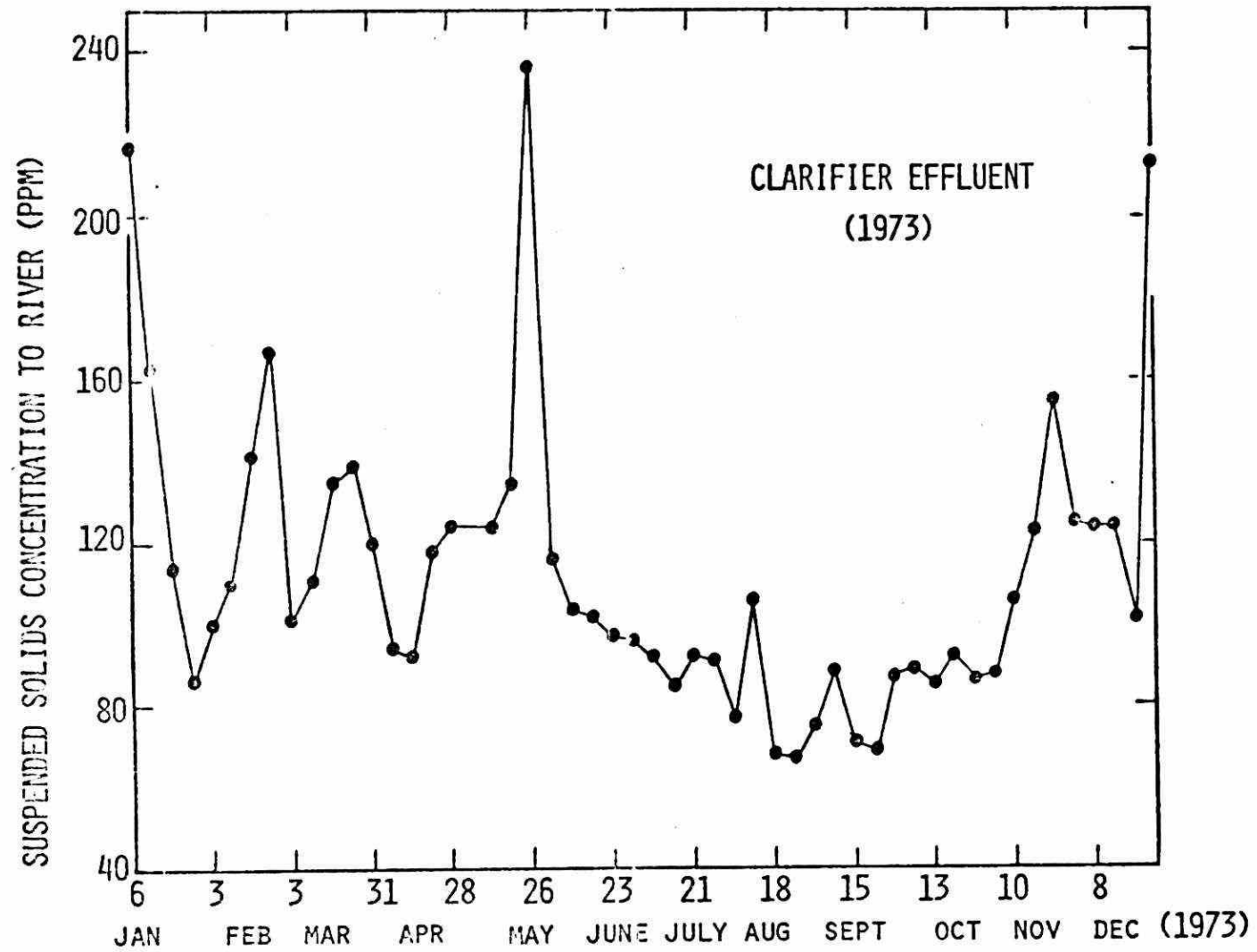


FIGURE 14 WEEKLY AVERAGE SUSPENDED SOLIDS CONCENTRATIONS FROM THE CLARIFIER TO THE ST. LAWRENCE RIVER

settled sludge. Separate testing for suspended solids and dissolved solids was maintained as usual in the various mill sewers to monitor origin of losses.

Results of testing the clarifier influent for lignin, sodium contents, pH, colour, suspended and dissolved solids were analyzed statistically, based on 75 observations selected at random from hundreds of test results. Significant correlations were found for pH and sodium ion concentration versus suspended solids concentration in the clarifier discharge, whereas no correlations were found for suspended solids in the influent or lignin in the influent with respect to clarified effluent suspended solids concentrations. However, another multiple variable linear regression analysis was performed by mill process engineers on the data obtained August 17, 18 and 19, 1973 during a period when the old evaporators were starting up, resulting in black liquor contaminated evaporator condensate. The regression equation obtained from 36 observations in this period is:

$$\begin{aligned} \text{S. solids out} &= 73.4 + 127.6 (\text{lignin}) \\ &\text{out} = 0.051 \text{ S. Solids} \\ &- 0.022 (\text{Na}^+) \text{ out} + \\ &0.00936 (\text{Na}^+) \text{ in} - \\ &0.679 (\text{pH}) \text{ in.} \end{aligned}$$

These data were used to show the clarifier performance on a statistical basis Fig. 15.

Where suspended solids, lignin and Na^+ concentrations are given in ppm, the lignin concentration which may be taken as an indication of black liquor concentration, has the strongest effect on clarifier suspended solids discharge according to this equation. For this intensive study period the probability of a given clarifier performance is shown in Fig. 15.

8. Nature of Effluent Suspended Solids

Ashing of effluent suspended solids at 600°C indicated that they were mainly inorganic.

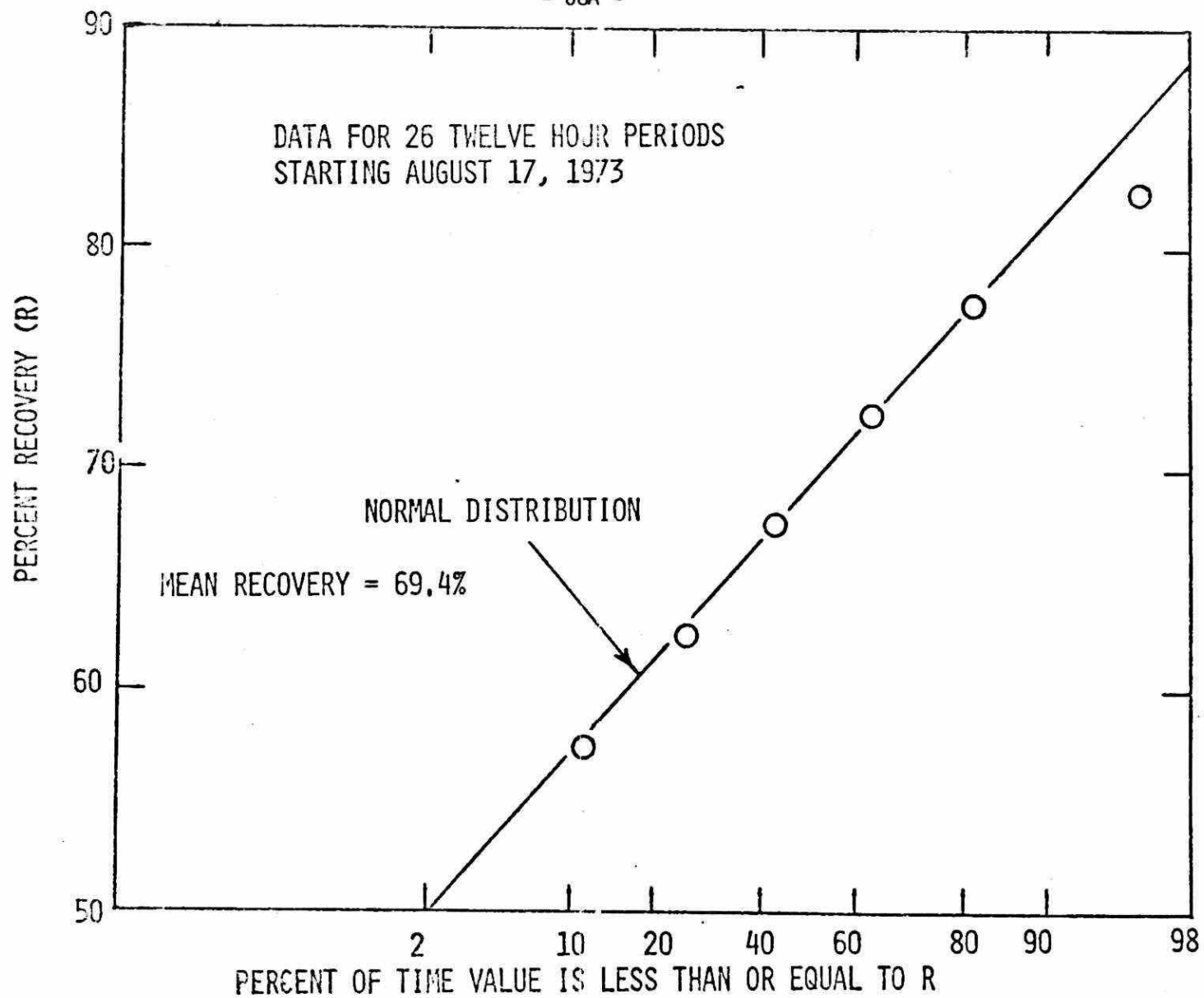


FIGURE 15 PROBABILITY OF OCCURENCE OF PERCENT RECOVERY FOR
CORNWALL CLARIFIER

Analyses by infra-red reflectance spectroscopy and X-ray diffraction showed them to be made up of major portions of calcium carbonate and filler clays from the paper machines. The particles size distribution of the solids in the clarifier effluent was measured using a Coulter Counter. Fig. 16 shows the results from an analysis carried out on October 18, 1973 using a fresh sample of clarifier effluent. The data followed a log-normal distribution with a geometric mean diameter and standard deviation of six microns and 1.50 (dimensionless) respectively. Many analyses over a period of several weeks indicated the mean particle diameter remained constant. Terminal velocities in water for these small particles are only 40 IGPD/ft.² which is 1/15th of the lowest clarifier rise rate. Hence, these suspended solids are essentially non-settleable. Also shown in Fig. 16 is a size distribution of the effluent solids that have passed once through the standard glass-fibre Reeve-Angel filter paper. Again, the data follow a log-normal distribution with a geometric mean diameter of 1.7 microns. From the data given in Fig. 16, the weight fraction removed by the filter paper was calculated to be 99%.

Secondly, a bacterial analysis of the clarifier influent and effluent streams was made. The bio-mass in the effluent was computed to be 0.015 ppm which is only 2.02% of the suspended solids concentration. Hence it was ruled out as being an important variable in the clarifier operation. Finally, a Zeta meter was used to determine the charge on the clarifier effluent suspended solids. An average of six readings of Zeta potential gave a value of -22 mv with values from -15 mv to -27 mv. According to Billings and Dehaas the Zeta meter is a very useful device in predicting the settleability of solids in waste streams. While test results are usually subject to considerable variation, they claim settling results are generally quite good for Zeta potentials in the range of 0 ± 5 mv. Poor settling is invariably encountered beyond ± 20 mv.

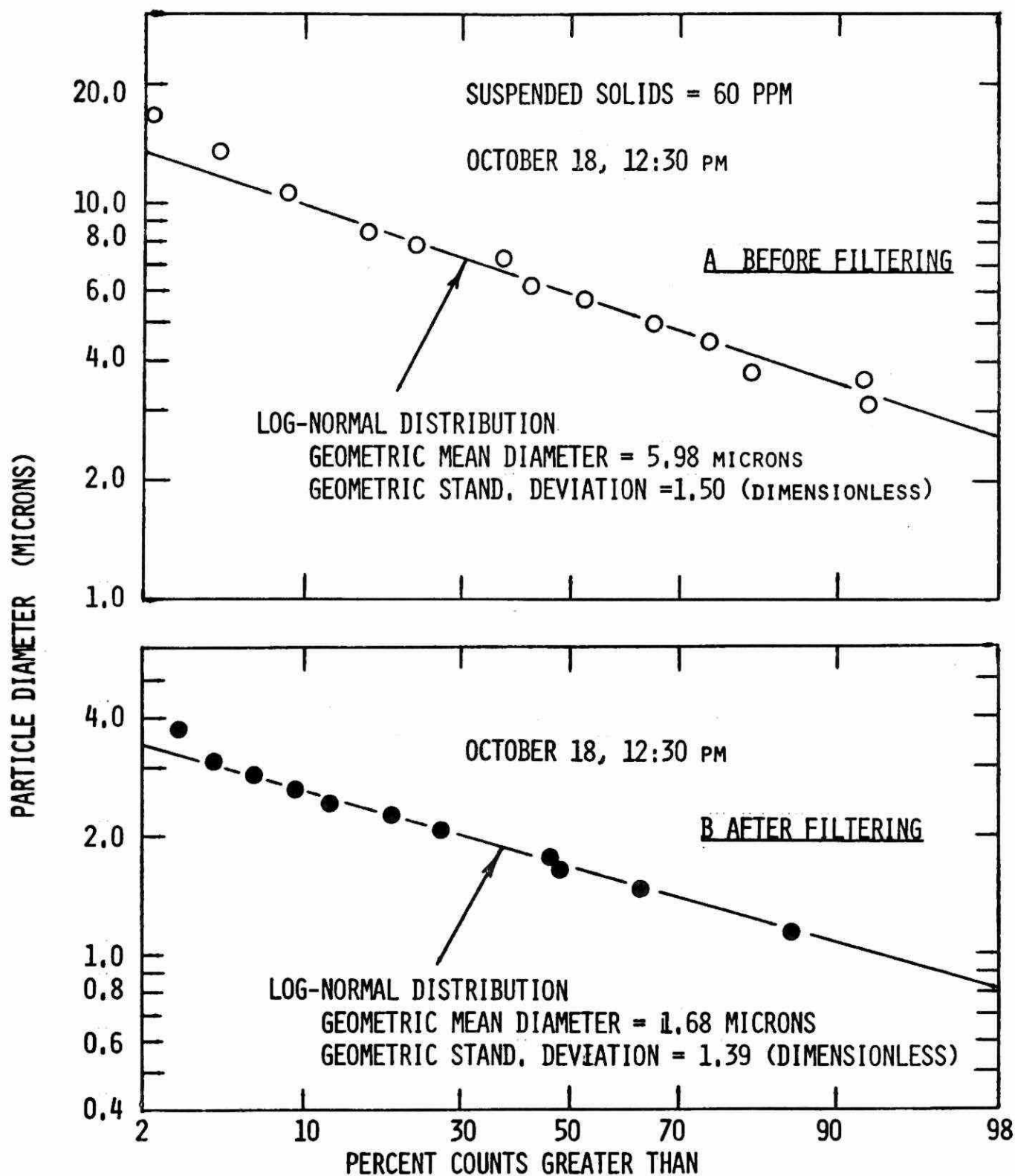


FIGURE 16 SIZE DISTRIBUTION OF CLARIFIER EFFLUENT SUSPENDED SOLIDS BEFORE AND AFTER PASSING THROUGH STANDARD REEVE-ANGEL 934AH FILTER PAPER (OCTOBER 18, 1973)

9. Experimental Verification of the Effect of Black Liquor Spills on Clarifier Suspended Solids Discharge Concentration

While lignin studies on the clarifier influent and statistical analysis did not dispel lingering doubts on the part of some operating personnel about the detrimental effect of black liquor on settling of suspended solids in the clarifier, it was decided to arrange a premeditated spill of a known amount of black liquor to the Kraft Mill sewers. Clarifier performance prior to the spill was good under the circumstances at 65 - 70 ppm suspended solids discharged from the clarifier. Samples of clarifier influent and effluent were collected every 10 minutes for at least 2 hours prior to the start of the spill, and continued during the spill which lasted 2 hours and for an additional 3 hours after the spill was stopped.

The results obtained are tabulated in Table 3 and results of lignin determinations on the clarifier influent and effluent is shown in Fig. 17.

A lag of 2.5 hours corresponding to the retention time in the clarifier showed up in the results, and from this point onwards the suspended solids in the clarifier discharge increased rapidly from test to test peaking at 160 ppm. Although there were variations in concentrations in incoming suspended solids, mostly originating from the paper machine effluents, the results showed a significant and definite detrimental affect of black liquor on the settling of suspended solids in the clarifier.

10. Clarifier By-Pass

With the failure of the spill collection systems installed to prevent discharges of black liquor in varying amounts as well as mud and green liquor dregs, plans were made and approved by Domtar and the Ministry of the Environment to improve the mud and dregs collection system, to install a Kraft sewer con-

TABLE 3

PERFORMANCE OF CLARIFIER DURING A CONTROLLED SPILL OF WEAK BLACK LIQUOR - CORNWALL (November 15, 1974)

TIME	Temp. °F		pH		Na ⁺ ppm		Susp. Solids ppm		Diss. Solids ppm		Lignin ppm	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
0920	72	72	7.9	7.1	154	139	164	90	720	1432	-	40
0900	73	72	8.0	7.3	172	139	148	81	720	1604	28	-
0940	72	72	8.0	7.3	162	126	86	80	720	692	-	-
0950	73	72	8.0	7.4	181	138	622	90	720	696	-	-
1000	73	72	8.1	7.3	146	126	1342	84	720	688	24	39
1010	72	72	8.3	7.1	172	146	200	85	720	656	-	-
1020	72	72	8.1	7.2	172	146	236	91	720	1044	-	-
1030	73	72	8.3	7.3	200	156	190	74	720	704	33	39
1040	72	72	8.0	7.3	181	156	228	79	520	688	-	-
1050	72	72	7.7	7.3	146	162	336	75	520	684	-	-
1100	72	72	7.8	7.2	133	162	282	78	480	668	26	39
1110	73	72	7.8	7.3	172	162	242	82	480	696	-	-
1120	76	72	7.8	7.3	924	162	294	81	7880	680	-	-
1130	75	72	11.1	7.4	1146	162	314	71	4480	684	1125	35
1140	72	72	11.4	7.4	1146	162	274	71	4800	624	-	-
1150	73	73	11.4	7.2	1086	154	242	69	4840	704	-	-
1200	74	73	11.4	7.2	1032	162	222	66	6520	684	1211	37
1210	74	73	11.4	7.3	1032	162	224	70	5080	648	-	-
1220	74	73	11.4	7.4	1200	162	230	80	5080	732	-	-
1230	74	74	11.4	7.4	1146	162	224	70	5040	684	1267	42
1240	78	72	11.5	7.2	1086	172	234	70	5080	688	-	-
1250	78	72	11.1	7.3	1086	181	206	62	5000	772	-	-
1300	76	73	11.1	7.6	972	181	240	64	4840	748	1233	44
1310	75	73	11.1	7.8	1032	191	520	64	4800	772	-	-
1320	75	73	11.2	7.8	1086	191	732	61	4760	788	-	-
1330	76	72	11.3	8.6	1086	231	426	60	4960	888	1267	98
1340	74	72	11.3	9.1	1200	265	368	67	5480	1052	-	-
1350	73	73	11.3	9.7	1326	543	384	75	6120	1564	-	-
1400	73	73	11.3	10.0	1326	584	348	87	5920	1976	1554	409
1410	73	74	11.4	10.3	1260	800	310	110	6040	2564	-	-
1420	72	74	11.4	10.6	1200	648	276	112	6440	3016	-	-
1430	73	73	11.3	10.6	1146	724	276	119	6120	3504	1574	940
1440	74	73	11.4	10.7	1086	724	302	118	6960	3704	-	-
1450	75	74	10.7	10.7	636	764	252	120	2760	3388	-	-
1500	73	74	10.5	10.7	540	800	478	122	2600	4032	593	1113
1510	73	74	10.4	10.8	468	800	620	132	2320	4096	-	-
1520	74	74	9.9	10.8	265	764	290	140	1440	4316	-	-
1530	75	74	10.1	10.7	289	688	974	158	1640	3808	343	976
1540	75	74	10.1	10.6	253	616	200	159	1430	3660	-	-
1550	74	73	9.9	10.6	289	616	326	160	1560	3552	-	-
1600	73	74	8.8	10.6	146	616	286	152	720	3508	-	-
1610	73	74	7.8	10.5	121	616	256	153	640	3332	21	852
1620	74	74	7.5	10.4	126	688	336	152	560	3176	-	-
1630	73	74	7.4	10.4	121	616	236	154	560	3740	24	702
1640	73	74	7.4	10.3	121	584	216	143	560	2940	-	-
1650	76	73	7.4	10.4	116	584	204	139	569	2768	-	-
1700	75	73	7.5	10.3	116	532	212	141	560	2684	22	689
1710	74	73	7.6	10.2	121	494	310	134	760	2544	-	-
1720	74	73	7.5	10.2	121	444	212	135	760	2448	-	-
1730	73	73	7.7	10.2	126	444	174	130	800	2400	23	602
1740	73	73	7.7	10.2	116	444	190	123	720	2368	-	-
1750	74	73	7.7	10.1	139	424	216	129	720	2276	-	-
1800	72	73	7.7	10.0	172	376	176	123	680	2140	26	469
1810	73	73	7.8	10.0	221	344	206	133	720	2076	-	-
1820	74	73	7.8	9.9	231	350	202	126	720	2036	-	-
1830	72	73	7.8	9.9	210	345	306	126	680	2000	28	420
1840	74	73	7.7	9.9	221	310	238	127	640	1904	-	-
1850	72	73	7.7	9.6	221	316	246	130	720	1880	-	-
1900	75	73	7.7	9.6	231	316	228	133	680	1840	44	369

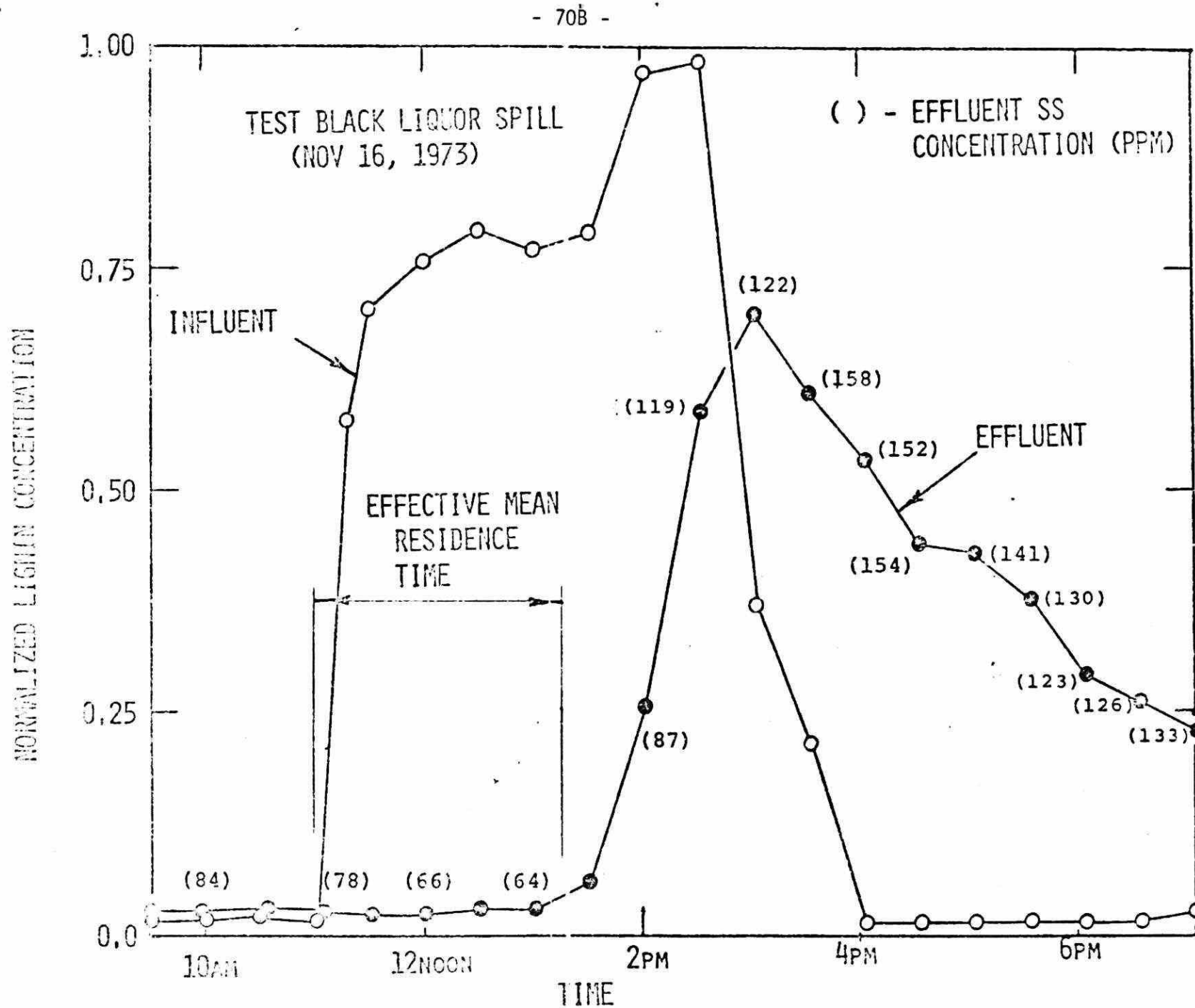


FIGURE 17 EFFECT OF CONTROLLED BLACK LIQUOR SPILL ON SUSPENDED SOLIDS CONCENTRATION IN CLARIFIER EFFLUENT

ductivity monitoring and alarm system and to provide a clarifier by-pass for effluents originating in areas prone to spills of black liquor. Acid and alkaline bleach plant effluents usually of low suspended solids but very foamy and high in volume were to be included in the by-pass which was to be installed as soon as possible, and tentatively be in operation by the end of December 1973. Due to difficulty in getting delivery of new equipment needed to replace an old Bird Centrifuge used to de-water lime mud and green liquor dregs, and similar delays in getting the equipment needed for the conductivity monitoring system, all efforts were put into designing and installing a clarifier by-pass with area pick up sumps and pumps to collect contaminated effluents. By March 9, 1974 the system was started up with gravity discharging effluents in the recovery furnace area and the evaporator areas and the digester and brown stock washer areas served by two sump pumps equipped with level controls. The acid bleach plant effluent was also discharged to the by-pass. The very high suspended solids in the clarifier discharge started to come down, but troubles with the sump pumps prevented the by-pass from working as intended.

Spills were getting by and contaminating the mill effluent to the clarifier. The alkaline bleach plant effluent was diverted to the by-pass later, about April 18, 1974. Despite dismal failure in keeping the by-pass sump pumps operational, clarifier performance once more continued a trend to reduced suspended solids discharge, although high levels of suspended solids were present in the incoming mill effluent (Fig. 18). For the first time, values of hourly tests of 20 to 30 ppm started to appear on April 29 and 30th. This turned out to be an up and down performance, but the downward trend has continued, indicating that the bypassing of most of the foamy liquor along with the intermittent discharges of green liquor dregs will result in greatly improved clarifier performance. Sewer testing in the mill during these good performance days showed

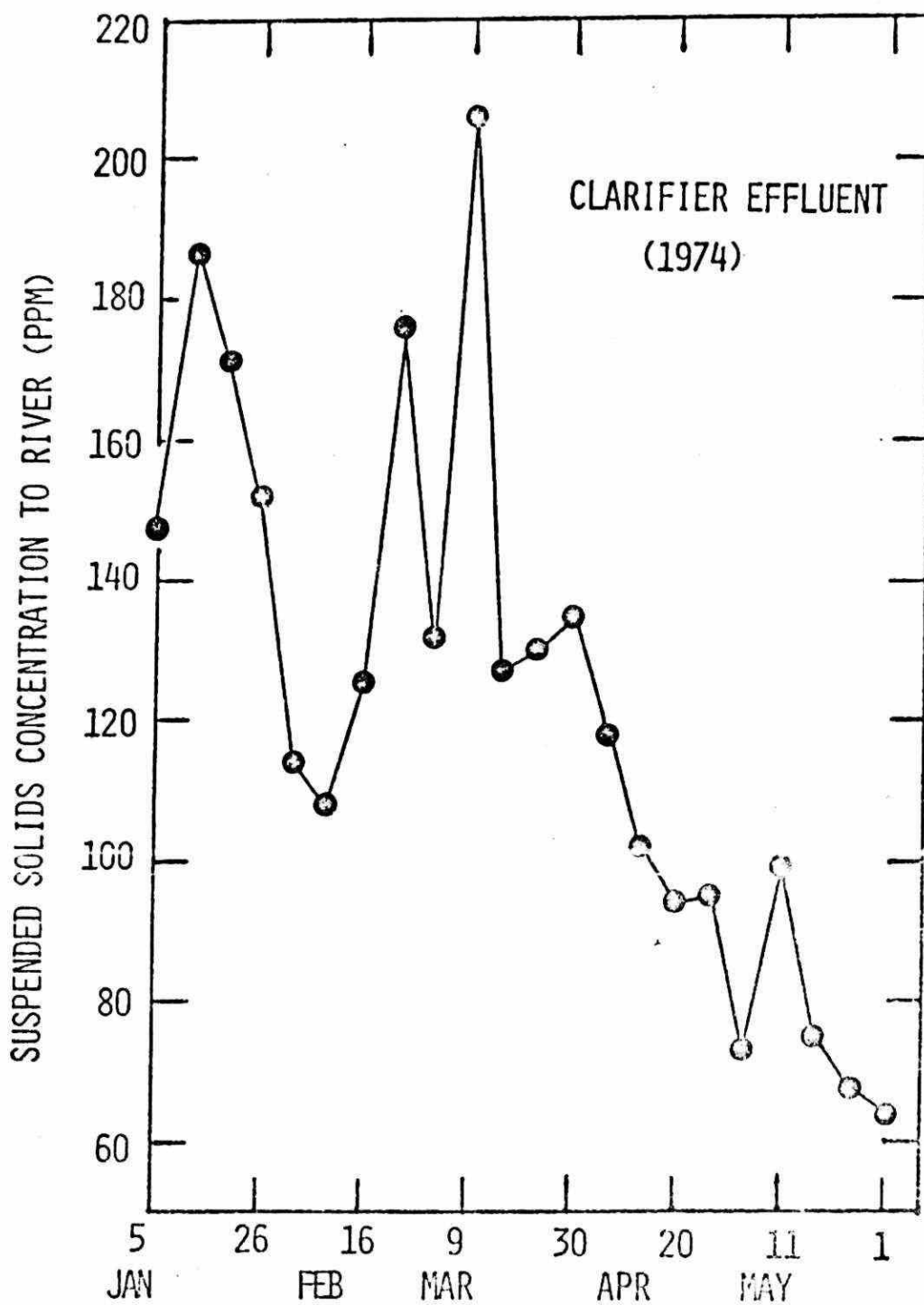


FIGURE 18 WEEKLY AVERAGE SUSPENDED SOLIDS CONCENTRATIONS
FROM THE CLARIFIER TO THE ST. LAWRENCE RIVER (1974)

in every case that on these occasions the various kraft mill effluents going to the clarifier were exceptionally clean, while losses from the paper mill were normal.

11. Conclusions

1. Generally it may be concluded that the suspended solids from a fine paper will settle well in a properly designed clarifier and will probably meet the 50 ppm suspended solids standard for effluent discharge. This is true, provided effective controls are applied to prevent green liquor dregs, lime, black liquor and foamy bleach plant effluents from reaching the clarifier.
2. The non-settleable suspended solids which are colloidal in nature consist almost entirely of clay, calcium and titanium dioxide.
3. Based on results with the pilot and full scale clarifier, it is believed that increasing the retention time several fold will have relatively little effect on the clarifier suspended solids removal efficiency.

Reference

1. Billings, R.M. and G.G. DeHaas, "Pollution Control in the Pulp and Paper Industry". Chap. 18 in text Industrial Pollution Control Handbook, Ed. H.F. Lund (1971)

Notation

IG - Imperial gallon
IGPD - Imperial gallon per day
IGPD/ft.² - Imperial gallon per
day per square foot
mv - millivolt
O D - Oven Dry
O D T - Oven Dry Tons
ppm - part per million
USGPM - U.S. gallon per minute



I. McKERRACHER

CHAIRMAN - SESSION 3
MR. I. McKERRACHER, P. ENG.,
DIRECTOR, REFUSE DISPOSAL DIVISION
DEPARTMENT OF WORKS
MUNICIPALITY OF METROPOLITAN TORONTO
CITY HALL, TORONTO, ONT.

"A Resource Recovery Centre
Incorporating
A Full Scale Experimental
Waste Reclamation Plant"

BY

J. K. WALTER

Special Projects Engineer
Kilborn Engineering Ltd.,
Consulting Engineers
Toronto, Ont.



J. K. WALTER

INTRODUCTION

The problems of solid waste management have been with us since mankind first banded together in families and tribes. At that time the accepted method of managing the problem was to move when the situation became untenable. Since then, both our customs and our waste products have altered considerably.

Present methods of handling solid waste, based largely on incineration, landfilling, and open dumping, are no longer acceptable, and have generated pressures for change.

- * Citizens groups have become increasingly aware of the depletion and wastage of our natural heritage with attendant environmental deterioration, and are pressuring for more efficient utilization of our resources.
- * Open dumping is a complete contravention of our modern environmental, health and aesthetic standards.
- * Landfill sites are becoming scarce and more remote.

The potential benefits of resource recovery based on the detailed analysis of the makeup of solid waste are tremendous. Implementation of a Resource Recovery Centre for a community of 100,000 could generate

a number of benefits and could effectively contribute to the preservation of our natural resources in:

- * Conserving up to 3,500,000 gallons of fuel oil per year if burned as fuel, or
- * Conserving up to 30,000 tons of paper and cardboard.
- * Producing up to 3,500 tons of reclaimed steel for remelt every year.
- * Recycling up to 4,500 tons of glass.
- * Conserving up to 700 tons of aluminum, copper, lead and zinc per year.
- * Saving 15 acres of land in the community for uses other than landfill.
- * Realizing savings of up to 1/3 of the operating cost and up to 60% of the capital cost of incineration (without heat recovery).
- * Allowing immediate re-use of the landfill area due to rapid stabilization of the ground.
- * Creating new job opportunities.
- * Providing increased flexibility for planning the uses of available public land.

SOME PRESENT PROBLEMS OF SOLID WASTE MANAGEMENT

The most pressing problems of our solid waste situation are:

1. The necessity of preventing environmental contamination resulting from waste disposal.
2. The need to conserve resources, including energy resources.
3. The accelerating increase in per capita production of waste at 5% per year which now brings the quantity to .7 tons per person per year. (Toronto Rates)
4. The proliferation of types of material discarded as waste which are rendering present disposal methods less efficient and effective.
5. The anticipated exponential increase in cost necessary to achieve effective solid waste management by present methods.

HISTORY

The Ontario Ministry of the Environment, in its assessment of the scope, complexity and seriousness of the problems, had decided that the situation required government action. Its investigation of the factors involved revealed that there are 6 different basic approaches which could alleviate the mounting problems of municipal waste management.

These approaches are:

1. Reduction in the quantity of material produced at the source.
2. Changes or control of the types of material used to simplify separation, recycling or reclamation.
3. Separation of waste at the source.
4. Construction of central reclamation plants.
5. Construction of processing facilities for separated materials.
6. Encouragement of re-use of reclaimed material and the development of new uses.

While realizing that action will probably be necessary in all of these basic approaches, the Ministry considered re-use, recycling and reclamation to be one of the best ultimate solutions to the increasing problems.

Before reclamation could be initiated as a viable alternative to present methods of disposal, a comprehensive study of all the extremely complex factors involved was essential.

Presently, no central reclamation plant or processing facility for separated material is in existence or proposed which is sufficiently comprehensive to be capable of providing information for a municipality to consider the construction of a working facility to handle its waste. Proposals from various companies have been designed with a preconceived bias toward a particular process or equipment, thereby rendering the information inappropriate for making reliable recommendations. It, therefore, becomes essential that a facility be constructed for testing in practice the various technologies theoretically feasible. It is also most unlikely that any one type of plan or process could serve the widely varying needs of all communities.

For these reasons it was proposed that an experimental reclamation plant be constructed as the first stage in the development of a resource recovery centre.

In view of its importance it was decided to set up a representative technical committee to initiate and supervise the project. The permanent members of the Joint Technical Committee for Resource Recovery are:

Mr. Wes Williamson
Assistant Director
Pollution Control Branch
Ministry of the Environment of Ontario

Mr. Eric Sanderson, Chief
Solid Waste Division
Environment of Canada

Mr. Ian McKerracker, Director
Refuse Disposal Division
The Municipality of Metropolitan Toronto

The establishment of the Resource Recovery Centre was to be done in two phases.

Phase I - Study, Report and Recommendations for the possibility of establishing resource recovery as an alternative to present methods of waste disposal.

Phase II- Detailed engineering and construction of an experimental Waste Reclamation Plant.

Phase I involved a detailed assessment of:

1. Makeup of solid waste.
2. Known and developing technology for handling solid waste, including all aspects of energy recovery.
3. Existing and potential markets for reclaimed products and their potential economic value.
4. Known and developing technology used in industry with possible application to municipal waste.
5. Short and long term research priorities for achieving the objectives set out.

It also required the development of:

Conceptual plant layouts for primary separation
Flowsheets and equipment lists
Criteria for site selection
Capital and operating cost estimates
Operating procedures
Management options
Recommendations

Plant is: The purpose of the Experimental Reclamation

1. To investigate and compare the suitability of

- alternative procedures, processes and equipment for the separation and reclamation of components of municipal wastes;
2. To determine the feasibility of separation and reclamation plants as an alternative to present methods of disposal;
 3. To examine the feasibility of staged or modular introduction of such plants;
 4. To investigate the additional processing required for the marketing of reclaimed materials;
 5. To investigate alternative outlets for such materials, and the methods and costs of handling;
 6. To develop criteria by which the capital and operating costs of various types of plant of various sizes can be reliably estimated;
 7. To develop criteria by which the environmental effects of reclamation, including the consumption of energy, can be gauged so that a reliable and complete comparison can be made between alternative processes;
 8. To provide facilities to other agencies and to industries for the installation and testing in practice of equipment, instrumentation and processes related to their particular fields.

The report, in 2 Volumes, was submitted to the Joint Technical Committee on April 26, 1974 and recommended the establishment of a 200 Ton/Day Experimental Resource Recovery Centre of which a Dry Primary Separation Plant was to be the first module

Kilborn Engineering Ltd. has, in the study submitted, suggested other prerequisites for establishing resource recovery as an alternative to present disposal methods. These would be:

1. The establishment of incentives for industry offering opportunities for:
 - * Increasing profits
 - * Expanding their operation
 - * Enhancing the public image
 - * Long term stability
2. The assembly of sufficient quantities of solid waste at the right location to make a processing operation economically viable.

3. The establishment of contractual obligations for the supply of minimum quantities for a period of time to make a processing plant an attractive investment.
4. The avoidance by municipalities of hastily constructing energy recovery systems based on known technology which are not adaptable to the emerging technology of resource recovery, and which carry large amortization burdens.
5. To receive guidance from industry in the initial detailed design phase of the Resource Recovery Centre, in any proposed control of the types of material used in packaging, and in the formulation of agreements for secondary processing modules.

Figure 1 shows what products will be obtainable from the experimental Primary Separation Plant and where it is hoped that industry will participate.

DESCRIPTION OF THE PLANT

The basic primary separation plant has been laid out to enable any of the known or developing technology to be tested and monitored. It will be able to provide information regarding power requirements for individual pieces of equipment, wear factors etc. so that it can provide accurate information regarding capital and operating costs for various sizes of plants.

In-plant facilities will enable different makes and types of equipment to be tested and monitored under operating conditions. Accurate data regarding noise, odour, and other environmental data will be obtained in the laboratory to enable the Ministry of the Environment to provide guidance and advice to other municipalities regarding resource recovery.

Basically, the plant contains weigh scales for determining the quantity of material brought in, a sampling, control and surge section, cardboard and paper recovery and baling department, a size-reduction section, and an air and gravity separation area. It will contain equipment for ferrous and non-ferrous, plastics and putrescible separation.

Equipment manufacturers will have an opportunity to test their products under actual operating conditions and it is hoped that this will lead to the more rapid development of equipment suited to the processing of solid waste.

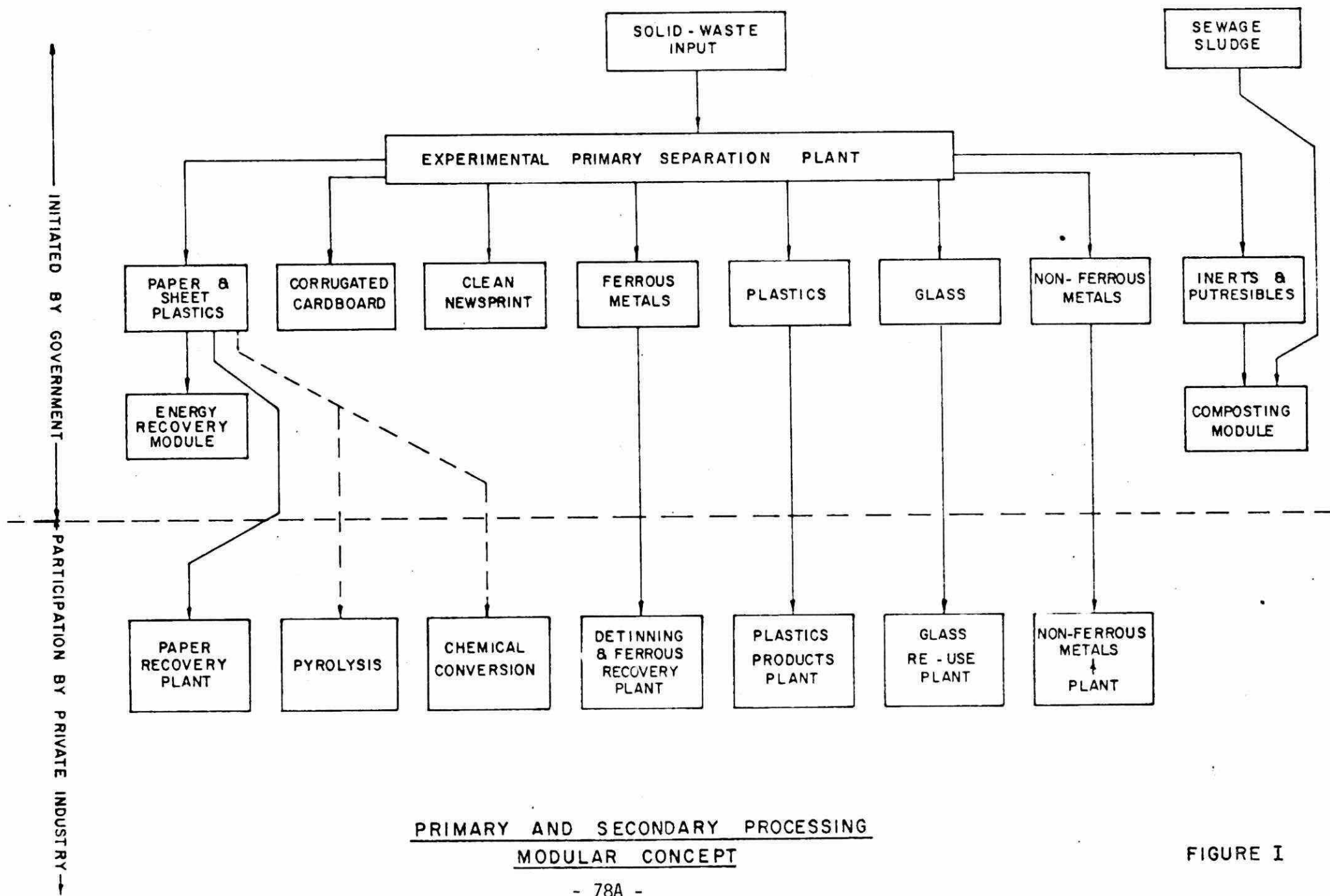


FIGURE I

The laboratory will contain facilities for analyzing basic waste and determining heat content, ash content, carbon, hydrogen, nitrogen and other elements. It will be capable of sampling and analyzing air and water emission, and will contain methods of determining the sanitary quality of solid waste before and after processing. It will also be capable of providing a bacteriological evaluation of solid waste, incinerator residue, compost, quench waters, leachates, stack emission and dust in and around processing modules that can be added to the basic plant.

Because of the advanced stage of composting, energy recovery, and ferrous metal recovery processes, and the possibility of their immediate application, it was considered advisable to construct these as part of the basic plant. Energy recovery systems in use at present involve large capital outlays which load a region with a massive 20 year amortization burden and contribute very little to reducing the cost of disposal. See Table 1. It is planned to use the energy recovery complex to develop a method of firing the combustible fraction in small boilers, so that it can be used in present industrial installations. The composting section will be used to investigate the possibility of using solid waste to reclaim presently denuded and scarified areas and attempt to restore them to their original verdurous condition.

The conceptual layout and architectural rendering attached (Fig. 2 and 3) was based on a complete investigation of known and developing technology in the field of solid waste management and industrial technology that might be applicable.

LOCATION

The location of the experimental Resource Recovery Centre requires consideration of two groups of criteria, major and minor.

The major factors considered were:

- * Social acceptability for the handling of solid waste,
- * Ample storage for solid waste,
- * Existence of a traffic pattern for the haulage of solid waste,
- * a long-life expectancy for the site
- * and tonnage of waste available.

Incinerator sites, transfer station sites or landfill sites generally were considered acceptable sites. The minimum area required was considered to be 10 acres.

TABLE 1

ECONOMIC COMPARISON OF EXISTING ENERGY RECOVERY PLANTS

BASED ON 500,000 TONS/YR. CAPACITY & 8½% AMORTIZATION

OVER 20 YRS. - 1973 COSTS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DESCRIPTION OF PLANT	CAPITAL COST	AMORTIZATION CHGES.PER TON	OPERATING COSTS PER TON	TRANSPT. CHGES. PER TON	TOTAL COSTS PER TON	MARKET VALUE PER TON	NET DISPOSAL COST PER TON
Incinerator -Accepts Whole Waste - Generates Steam	\$27,000,000.00	6.00	2.63	INCL	8.63	NIL	8.63
Incinerator -Similar to Edmonton Plant England -Generates Steam & Power - Recovers Metals	\$29,000,000.00	6.39	5.50	INCL	11.89	3.58	8.31

Notes: All costs are rough approximations and should only be
used for comparison purposes.

Col. 5 = Col. 2 + Col. 3 + Col. 4
Col. 7 = Col. 6 - Col. 5

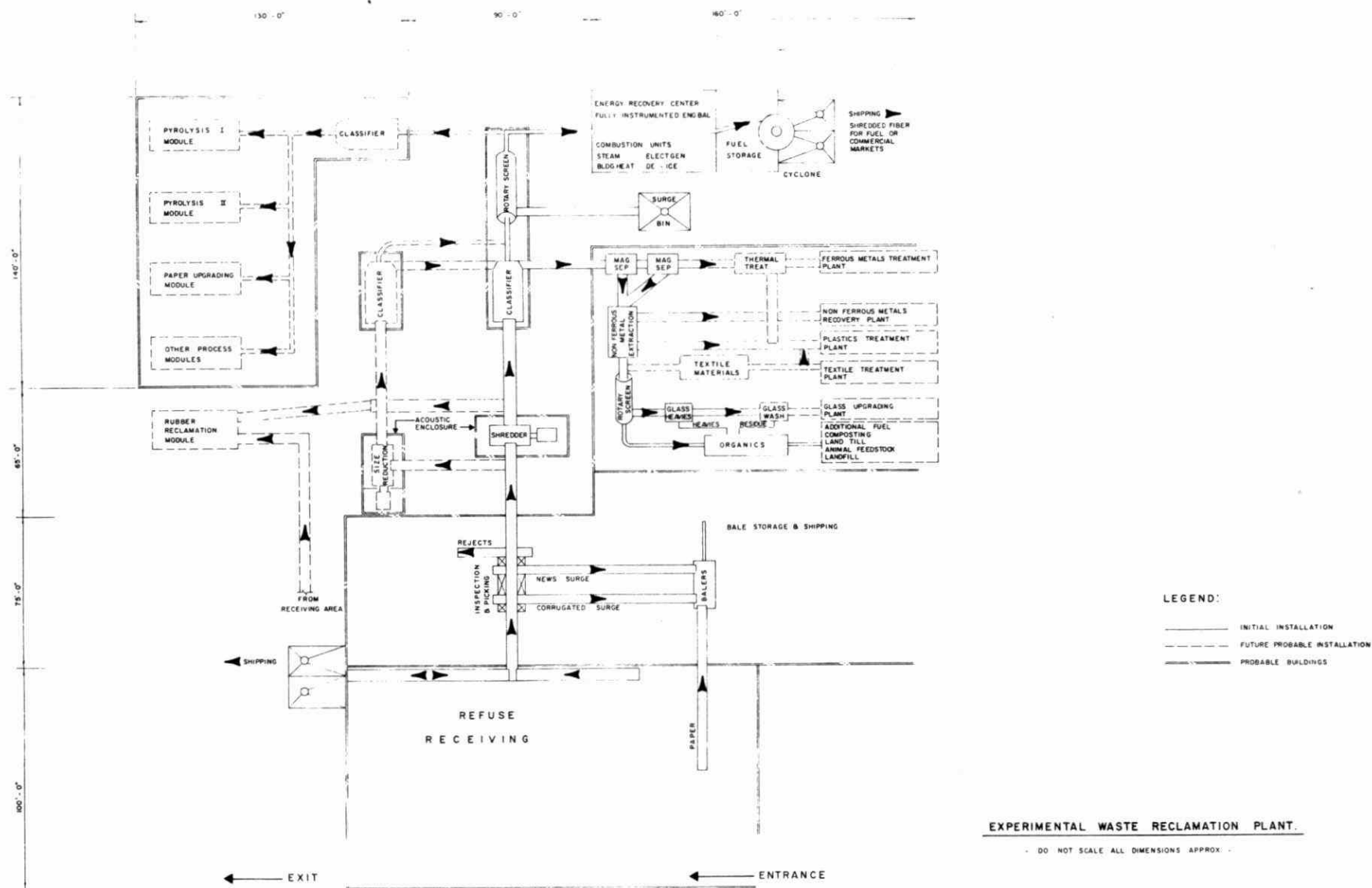


Fig.3

[illegible]

SPECULATION ON TRENDS

In a number of cities in the U.S.A., both collection and disposal of municipal waste is being done by private contractors specializing in solid waste management. In some cases, however, private contractors have been unable to cope with the problems of disposal so that the responsibility has reverted back to the municipalities.

In Canada, our municipalities have generally elected to maintain the responsibility for the collection and disposal of solid waste, considering it one of the services provided.

The processes suitable for resource recovery from solid waste have been divided into four categories and are listed below.

1. Composting processes
2. Energy recovery processes
3. Material recovery processes
4. Chemical and miscellaneous processes

Composting processes have the least potential recoverable value; energy recovery is limited to approximately \$8.00 to \$9.00 per ton, and material recovery and chemical conversion has the maximum potential. Composting and energy recovery processes are in an advanced stage of development, while material recovery and chemical processes are still in the early stages.

Successful construction and operation of material recovery processes and chemical processes, in particular, will require the detailed technological expertise which private industry has developed. It also requires the sales and marketing organizations already established by private industry and the ready access to markets for redirecting the reclaimed products into our economy.

The development of the modular concept of resource recovery will enable the municipalities to retain the responsibility for the overall disposal of solid waste and also enable private industry to participate in a manner compatible with their present aims and objectives.

This can be done by dividing a resource recovery centre into a primary separation module operated by the municipality and with private industries operating secondary recovery plants, using products from the primary separation plant as raw materials for their plants. See Figure 1.

The development of this concept was also given impetus by preliminary estimates which indicate that no single segment of solid waste could, on its own, support a primary separation plant, as well as the secondary processing module.

The construction of the proposed experimental resource recovery centre is a prerequisite of paramount importance to the establishment of resource recovery as an alternative to landfill and incineration.

Intensive co-operation between government and industry can, within a few years lead to the effective establishment of resource recovery as a preferable alternative to present methods of waste management and enable us to reap the benefits of the technology of the era in which we live. Present incinerator, transfer stations and landfill sites which have the established traffic and environmental patterns necessary for the handling of solid waste, are the logical sites for the future primary separation plants and in some cases, for the secondary processing plants.

Each plant will, however, require a comprehensive system analysis involving all the complex variables of the economics of each of the products available and the quantities. In some cases, a Primary Separation Plant may serve several regions with some secondary products produced at the site, and others transported to an established secondary processing plant in another area.

The Experimental Reclamation Plant can furnish the basic data for these evaluations, and wholehearted participation by industry can bring us closer to the realization of the potential shown in column eleven of Table 2.

"The Management of Concentrated
Liquid Waste & Solid Waste in
Industry"

BY

O. V. Martini and D. Sexsmith

James F. MacLaren Limited
Environmental Engineers and Scientists
Willowdale, Ontario



O. V. MARTINI

INTRODUCTION

During the past eight years, the firm of James F. MacLaren Limited has undertaken 12 major solid waste management studies for 10 Canadian municipalities, one for the International Nickel Company and one for the City of Ibadan in Nigeria. Although the main objectives in all of these studies was to establish refuse quantities and optimum handling and disposal methods, in almost every instance it was also necessary to identify and quantify the area's troublesome industrial wastes, both liquid and solid. For the purpose of this paper, the term "liquid industrial waste" will be assumed to include all fluids which cannot be discharged to a sanitary or storm sewer.

Using information obtained for the foregoing studies, together with supplemental information provided by several industries and Ontario's Ministry of the Environment, it will be the purpose of this paper to:

- (i) review several new practices adopted by industry in the management of its solid and liquid waste problems during the past two decades in the hope that such descriptions might assist other industries facing similar problems.
- (ii) identify a few persistent problem areas in the hope that some inventive mind - presently unfamiliar with the existence of such problems - might devise some economical and worthwhile solutions.

The solid waste studies which we have carried out to date extend from Moncton, New Brunswick to Victoria, British Columbia, and as far north as Whitehorse in the Yukon. However, because of time limitations, this paper will confine its comments to the Ontario scene.

HISTORICAL REVIEW

Prior to 1956, the regulatory functions associated with pollution abatement and solid waste management in Ontario were largely the concern of the Provincial Department of Health and of the local Medical Officers of Health who were appointed under the Public Health Act then in effect. In 1956, the Province took the first of several steps aimed at providing more stringent regulations for the protection of the environment with the passage of the O.W.R.C. Act. The Ontario Water Resources Commission (OWRC) became fully operative in 1957 with the appointment of staff, mainly by direct transfer of a large part of the Sanitary Engineering Division of the Department of Health. Under the OWRC Act, the Commission was granted broad powers and responsibility for the development, treatment and management of the Province's water resources including, the power to prosecute municipalities and industries which had inadequate water pollution control facilities.

During the mid 1960's, the Air Management and the Waste Management agencies were established within the Department of Health and in 1969 both were transferred to the Department of Energy and Resources Management. In 1971, the Air Management and Waste

Management branches were merged to form the new Department of the Environment. Late in 1971 the agencies responsible for the control of pesticides, and private water and wastes also joined the Department of the Environment. During a major re-organization of the Provincial Government, in 1972, the OWRC and the Department of the Environment were integrated to form the Ministry of the Environment.

In addition to the OWRC Act of 1956, other legislative milestones were:

- (i) The Air Pollution Control Act - 1967
- (ii) The Waste Management Act - 1970
- (iii) The Environmental Protection Act - 1971

CASE HISTORY NO. 1 - FLY ASH

Our first solid waste study was carried out in 1966 - 1967 for the Municipality of Metropolitan Toronto, and data collected on that occasion established that the most voluminous industrial solid waste of the area was fly ash and bottom ash from Ontario Hydro's two local thermal generating stations. The current and projected quantities given us by Ontario Hydro at the time were:

TONS PER YEAR OF ASH FROM THE R.L. HEARN & LAKEVIEW G.S.

<u>YEAR</u>	<u>FLY ASH</u>	<u>BOTTOM ASH</u>	<u>TOTAL</u>
1966	230,000	58,000	288,000
1967	250,000	62,000	312,000
1968	400,000	100,000	500,000

In analyzing the above quantities, it is important to bear the following facts in mind:

- (i) The two generating stations were burning coal imported from the U.S. in 1966, and, at Lakeview, this is still the case. The Hearn station, however, now uses natural gas most of the time but has "dual-firing" capabilities. If Western Canada coal is substituted for U.S. coal in future, the volume of ash per ton of coal burned could nearly double.

- (ii) The Lakeview station underwent a major expansion in the late 1960's from 1200 to 2400 megawatts, while the Hearn station has remained at 1200 megawatt capacity.
- (iii) Hot uncompacted fly ash weighs about 45 lb. per cu. ft. when it leaves the stack. After being wetted and compacted in trucks, the unit weight increases to approximately 70 lbs. per cu. ft.
- (iv) The content of fly ash may be expected to vary appreciably, especially with respect to carbon content if the plant is handling "peak" rather than "base" loads. (Locally, the base load is handled by our hydro and nuclear stations while the thermal stations handle peaks). A search of the literature⁽¹⁾ indicates the following major chemical compounds may be found in fly ash:

SiO ₂	40 to 60%
Al ₂ O ₃	20 to 30%
Fe ₂ O ₃	5 to 25%
C	2 to 15%
Ca O	1 to 6%
TiO ₂	0.5 to 2%
Mn O	0.5 to 1.5%
K ₂ O	0 to 2%
Na ₂ O	0 to 1%
P ₂ O ₅	0 to 1%
SO ₃	0 to 1.5%

- (v) Currently the Lakeview Station generates about 400,000 tons per year of fly ash and 100,000 tons of bottom ash.⁽²⁾

In 1966, essentially all fly ash generated in the Metro Toronto Planning Area was being used as landfill and today this picture is little changed. There is every indication, however, that in the very near future (6 to 24 months) this picture will alter significantly and that the bulk of Hydro's fly ash will be processed to produce lightweight aggregates for concrete products, iron oxide and pozzolamic additives for concrete as shown schematically in Figure 1.

Assuming that full scale production of by-products from fly ash become a reality - and the markets and economics have never been more favourable than they are today - Ontario Hydro could realize an income in the region of \$3 to \$5 per ton or more from a solid waste that now costs from \$1 to \$2 per ton for disposal as landfill. (It must be appreciated that the inflationary tendencies of recent months, which are likely to continue for a while, could markedly alter the foregoing prices for fly ash products).

CASE HISTORY NO. 2 - SPENT PICKLE LIQUOR

"Spent pickle liquor" or "waste pickle liquor" are terms commonly used in the steel industry to describe discarded inorganic acid solutions which may have been used to dissolve oxide layers (including "rust" and "mill scale") from the surface of iron and steel products. Sulphuric and hydrochloric are the most common acids used for steel pickling, usually at solution strengths in the region of 10% to 15% when fresh. After processing several tons of steel, the dissolved iron content of the pickling solution gradually increases to a level of some 15 to 20% while the acid content diminishes to the range of 2 to 5%; when these conditions occur, pickling rates become unacceptably slow resulting in replacement of the "spent" solution with a fresh one.

In 1966, over 3 million gallons of spent pickle liquor were generated in the Metro Toronto Planning Area which did not receive any form of chemical treatment on site. Some of this waste acid was being used for sludge conditioning at the Humber

FLOW SHEET FOR FLY ASH PROCESSING

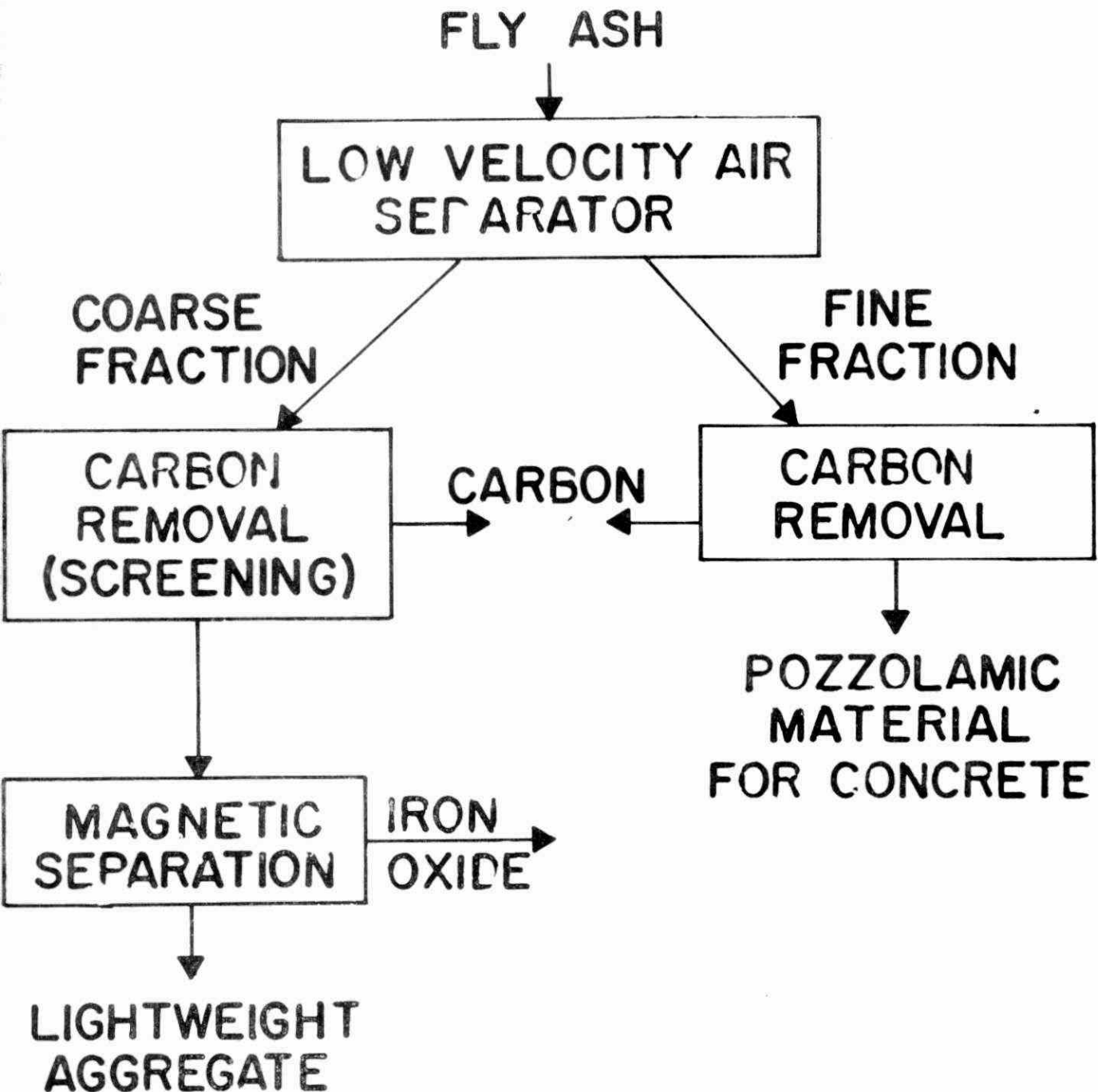


FIG. 1

Sewage Treatment Plant but the bulk of it was simply impounded in lagoons and allowed to evaporate and/or soak away. Whenever the lagoons were filled, local haulers were called in to remove a designated volume by tank truck to one of a number of landfill sites which accepted liquid industrial wastes. It should also be mentioned at this point that a number of intermediate-sized industries such as Wimco Steel in Rexdale had installed acid recovery facilities by 1966 and the crystallized iron salts (mainly ferrous sulphate hepta-hydrate) were being disposed of in landfill sites for the most part (limited quantities were used for pigment manufacture).

In the intervening eight years since 1966, treatment facilities have been installed at all of the major complexes in Metro Toronto which formerly had spent pickle liquor problems; in general, these take the form of simple neutralization tanks in the case of the smaller plants and recovery facilities at the larger ones.

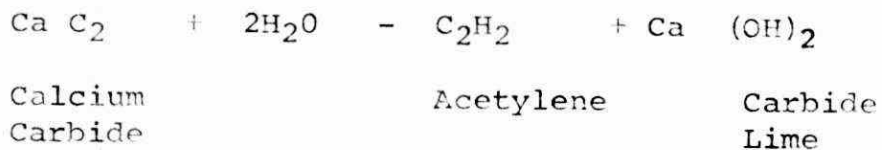
In Hamilton, Ontario, Canada's two largest steel companies solved their spent pickle liquor problems on a grand scale with the expenditure of many millions of dollars. Briefly this involved:

- (i) conversion of all major lines from sulphuric acid to hydrochloric acid pickling. Although the hydrochloric acid is costlier, this process change offered a number of advantages including faster and cleaner pickling, lower acid consumption (therefore less wastewater) and less attack on the base metal.⁽⁴⁾
- (ii) installation of treatment facilities which recovered the two basic ingredients of spent pickle liquor (free acid and an iron salt) in useable or marketable form.

With the completion of the acid recovery system in Hamilton in 1971, the era of discharging waste pickle liquor into Hamilton Harbour came to an end.

CASE HISTORY NO. 3 - CARBIDE LIME

Carbide lime is a by-product generated during the manufacture of acetylene from calcium carbide thus



In 1966, over 6 million gallons per year of carbide lime were generated by industrial plants in Metropolitan Toronto and essentially all of this was either impounded on site or disposed in landfills. Various studies were carried out to test the feasibility of using carbide lime for (a) sludge conditioning (b) neutralization of spent pickle liquor and (c) quicklime production but none were successful in opening up markets for this by-product.

Today, the Metropolitan Toronto picture remains essentially unchanged so far as markets for carbide lime are concerned. The volumes, however have dwindled to approximately 60% of the 1966 level largely because of Canadian Liquid Air's decision to close their Toronto plant and supply the Southern Ontario market from a plant in Varrennes near Montreal. In addition, increasing quantities of acetylene have been manufactured from hydrocarbons (e.g. natural gas) in recent years rather than calcium carbide, while in some manufacturing processes, ethylene and propylene have replaced acetylene as intermediates.⁽⁴⁾ As a result of these latter two developments, the production of acetylene from calcium carbide has tended to stabilize rather than increase so far as the Canadian picture is concerned. (Statistics Canada cites a growth of less than 1% per year for acetylene from calcium carbide during the past eight years).⁽⁵⁾

CASE HISTORY NO. 4 - FOUNDRY SAND

Following repeated usage, foundry sand moulds and cores gradually deteriorate due to accumulations of metallic particles, burned clay, carbonaceous materials and/or other binding agents (common binding agents include bentonite and other clays, oils, urea). Since the 1940's, different

sand reclamation systems have been devised depending on the nature of the impurities, e.g.:

- (i) Wet Systems: These systems comprise an agitation tank where a sand water mixture is mechanically agitated to promote multiple collisions between particles and a classifier which subsequently separates fine impurities from the sand grains. After draining the water, the sand is dried and re-used. Such systems are effective for clay-bonded sands but less effective in the case of organic bonding agents.
- (ii) Thermal Systems: These systems utilize a multiple hearth furnace wherein used sand is fed in at the top, heated to 1300°F and ploughed downward from shelf to shelf within a gas fired chamber. These reclaimers are excellent for destroying carbonaceous and organic binders but much less effective with clay.
- (iii) Dry Systems: The most recent, and perhaps the simplest of the present day reclaimers utilize low pressure blowers and nozzles to create a high velocity stream of air capable of keeping used sand particles in suspension in confined vertical tubes. The resulting impact and attrition between particles removes undesirable coatings from the sand grains and these are then swept away by the air stream to dust collectors. In developing this type of reclamation system after World War II, the manufacturers emulated a technique used for many years for backwashing rapid sand filters at water treatment plants.

The economics of foundry sand reclamation will vary with scale of operation and nature of impurities as exemplified by the following:

(a) Canron Limited - St. Thomas, Ontario

This is a large modern and highly mechanized foundry whose main products are brake shoes for railway cars and municipal castings. The Company's sand reclamation and bag house system cost about \$300,000 in 1963 and is capable of processing 200 tons per hour. Without the system, the foundry would use in excess of 500 tons per day and their current cost for sand is \$14.00 per ton delivered. The present installation paid for itself in less than two years and Canron's foundry sand requirements are now only 10 tons per day for make-up purposes.

(b) Ex-Cell-O Corp. of Canada Limited - London, Ontario

This medium-sized foundry recently commissioned a new sand reclamation facility which cost \$165,000 installed. Before purchasing the equipment, the Company was spending between \$700 and \$1000 per day to purchase some 60 to 80 tons of new sand and to dispose of a comparable volume of used material. With the reclamation equipment, the cost of purchasing new sand and disposal of used is expected to drop by at least 80%.

CASE HISTORY NO. 5 - FORD MOTOR CO. - OAKVILLE, ONT.

The Ford Motor Company's plant in Oakville, Ontario is fundamentally an assembly plant capable of turning out some 50 to 55 passenger cars and 35 trucks per hour (1,800 vehicles per day). It will be appreciated that an operation of this magnitude can generate a staggering volume of refuse mainly in the form of cardboard boxes, wooden crates, wire-bound boxes, timber pallets, waste paper, etc. In fact, prior to 1970 when most of the Company's refuse was going to Oakville's sanitary landfill site, the quantities averaged in the region of 2000 tons per month.

In recent years the Company has taken the following noteworthy steps to reduce the refuse volume:

- (i) in 1972 the power plant was converted from a coal-fired to an oil-fired operation, thereby eliminating a need for ash disposal.
- (ii) Timber pallets and crates are now sorted by an outside contractor (Auto Pallets & Boxes Limited) who recycles all suitable lumber while landfilling the unsuitable material.
- (iii) The automobile assembly plant segregates, bales and sells all clean cardboard and discards that which is contaminated with plastics, waxes, staples, adhering wood, etc. Reclaimed cardboard amounts to about 15 tons per day and sells for about \$50 per ton; sorting and baling cost the Company in the region of \$15 to \$18 per ton. In view of this profit-situation, it has now been decided to segregate and sell clean cardboard from the truck plant starting this summer (1974).
- (iv) Later this summer all waste wood and cardboard that is unsuitable for recycle will be broken up by a newly installed shredder to ease handling and reduce the volume requiring disposal.

It should be noted at this point that many other establishments in Southern Ontario have recently installed shredding and baling facilities for the purpose of reclaiming cardboard boxes for recycle; this includes breweries, liquor stores and supermarkets.

CASE HISTORY NO. 6 - POTATO PROCESSING

Delegates who attended the 1969 Ontario Industrial Waste Conference in Niagara Falls heard an interesting paper by Armstrong and Boyko⁽⁸⁾ which described the treatment facilities constructed by Salada Foods Limited in Alliston to treat wastewaters from its potato processing plant. Treatment at that time comprised grit removal, screening, primary treatment followed by biological treatment and polishing lagoons. All solids removed from the various processes

were disposed of on surrounding farms owned by the Company when weather permitted; in winter, sludges were disposed of in holding ponds for subsequent disposal on land during the summer months.

Since that paper was presented, the Company has steadily upgraded its facilities under the able direction of the plant superintendent, Mr. A. Robson. The most noteworthy of the modifications perhaps were (i) the installation of improved screening facilities and (ii) the introduction of sine-wave peelers which retained the peel in the process plant rather than releasing it as an aqueous waste. These two modifications reduced the solids load on the treatment plant by an estimated 50% and enabled the operators to convert one of the primary clarifiers into a thickener. In addition, the primary sludge, screenings and peel which were formerly disposed of on land by Salada are now trucked away to a farm near Kitchener and used as cattle feed.

CASE HISTORY NO. 7 - METAL FINISHING

In this context, metal finishing will be taken to mean all electro plating and similar operations including electroless plating, painting, anodizing, conversion coatings, etc.

During the past twenty years, the metal finishing industry has had to recoil in the face of strong pressure from regulatory agencies and environmentalists because so many of its wastewaters contain highly toxic substances. Under this pressure, the industry has devised a number of ingenious process changes and pollution abatement measures many of which have already formed the basis of interesting technical papers. Because of time and space limitations, we are listing those which we consider particularly noteworthy and which have been utilized by Ontario industries:

- (i) introduction of many new plating baths containing fewer toxic substances e.g. low cyanide and chloride zinc baths in place of traditional cyanide baths;

- (ii) use of counter-current rinsing, fog sprays and dragout recovery tanks to minimize wastewater volumes;
- (iii) use of mechanical agitation, improved racking and draining to conserve chemicals and reduce wastewater strengths;
- (iv) in-line or integrated treatment of rinsewaters;
- (v) electro coating and **powder** coatings as replacement for more traditional painting techniques.

In Ontario, the most widely-used methods of treating wastewaters from electroplating shops has been chemical treatment to destroy cyanides and reduce hexavalent chromium followed by pH adjustment to precipitate heavy metal ions. The metallic hydroxide sludges resulting from such treatment continue to pose a serious disposal problem for electroplaters and is sincerely hoped that these valuable "ores" will soon find "recycle outlets".

CASE HISTORY NO. 8 - IBM CANADA LIMITED

Prior to 1973, IBM's plant in Don Mills, Ontario, included facilities for the manufacture of magnesium cylinders and zinc plates that were used in the Company's punch card and manufacturing department, to print computer cards, business forms, cheques, etc. The wastewaters generated by this operation were similar to those from a small metal finishing operation and generally averaged less than 1500 gal. per day. An inventory showed that 27 different chemicals (e.g. nitric, chromic and phosphoric acids) were used by the department on an intermittent basis and that the wastewaters included such contaminants as heavy metals and chromates in trace quantities.

Following a complete review of the operation, management decided to phase out the electro-type manufacturing facility and to replace it with a patented "Nyloprint Electro System" from Europe which substituted nylon plates and cylinders for the magnesium and zinc units at a cost of approx-

imately \$50,000. This process change reduced chemical usage from the twenty-seven chemicals previously mentioned to a single organic solvent (used for etching nylon) which may be recovered by fractional distillation.

TRENDS AND CONCLUDING REMARKS

In carrying out various solid waste studies during the past eight years we have noted a number of encouraging trends which we hope will continue; these include the following:

1. Appointment of Environmental Co-Ordinators

A great many companies both large and small have, in recent years, appointed "environmental co-ordinators" to study solid and liquid waste problems on a broad corporate basis. We are convinced that this approach has been much more successful and in the long-run much more economical to industries than earlier traditional approaches of delegating such responsibilities to individual plant managers who probably haven't the time or interest to seek out the optimum solutions.

2. Recycling of Materials

We have observed a steady trend towards recycling of more and more materials in recent years such as scrap metal, various grades of paper, used oils and glass. Dealers in these areas are now better organized than ever before and it is to be hoped that the economic picture continues to favour their operations. Especially encouraging is the increased use being made of abandoned automobiles, newspapers, non-ferrous metals, beverage cans and fly ash. Targets for future recycling should include discarded appliances, used and rejected tires, metallic hydroxide sludges from the treatment plants of electroplating shops, and phosphogypsum from fertilizer plants manufacturing phosphoric acid.

3. Regional Disposal Facilities

The establishment of sizeable regional disposal facilities for both liquid and solid wastes in several parts of Ontario represents a major

improvement over the earlier situation in which many more smaller and often inferior facilities existed. Noteworthy examples include the privately owned liquid waste disposal facilities at Corunna and Mississauga and the municipally owned landfill sites operated by Metro Toronto. With the establishment of several new Regional Municipalities with responsibility for refuse disposal, we see a continuing trend in this direction with attendant savings for many industries and communities.

4. Tax Incentives

In recent years the Federal and Provincial Governments have granted sales tax exemptions on a range of equipment used for pollution abatement purposes. It is to be hoped that these policies will be continued and perhaps broadened in scope.

5. Research

Some 10 to 15 years ago, pollution abatement research was largely the domain of a few chemists and environmental engineers working with restricted budgets. Today we have a much healthier picture both with respect to financial assistance available and the number of disciplines involved.

CONCLUSION

The accomplishments of Ontario industries in the management of their solid and liquid wastes during the past two decades have been impressive and - unlike the "prophets of doom" - we are looking forward to even greater accomplishments during the 70's and 80's.

REFERENCES

1. Ballance, R.C. et al - Fly Ash As A Coagulant Aid In Water Treatment 1966 - U.S. Bureau of Mines, Report of Investigations 6869.
2. Mills, R.H. - Fly Ash - Pollutant or Pearl University of Toronto publication "Engineering Forum", No. 23 February 1974.
3. Report and Technical Discussion on Refuse Disposal For The Municipality Of Metropolitan Toronto - May 1967, by James F. MacLaren Limited, Consulting Engineers, Toronto in association with Black and Veatch Consulting Engineers, Kansas City, Mo.
4. Anon- Chemistry In The Economy, 1973 Publication Of The American Chemical Society
5. Stevenson, E. - Technical Representative, Canadian Liquid Air Limited - Toronto Private Communication.
6. Thorn, I. - Technical Representative, Liquid Carbonic Canada Limited - Toronto, Private Communication.
7. Watson, D. - Technical Representative, Canadian Oxygen Limited - Private Communication.
8. Armstrong, T.D. and Boyko, B.I. - Treatment of Potato Processing Wastes At Salada Foods Limited, Alliston - Proceedings, XVIth Ontario Industrial Waste Conference 1969.
9. Good, R.D. - Fir Bark Conversion Route - Chemical Engineering, May 27, 1974.
10. Ontario Hydro Annual Report - 1972.
11. Report on Refuse Disposal For Central Ontario Joint Planning Board December 1968 - by James F. MacLaren Limited.

12. Report On Solid Waste Disposal For The City Of London, Ontario 1970 by James F. MacLaren Limited.
13. Report and Technical Discussion On Solid Waste Management For The County of Halton, May 1974.
- 14 Report And Technical Discussion on Solid Waste Management For The National Capital Area - October 1973 - by James F. MacLaren Limited, In Consortium with J.L. Richards and Associates Limited, Labrecque Vezina and Associates and D. Wm. Carr and Associates Limited.



J. P. NUNAN

"Landfill Contaminant Flux - Surface
& Subsurface Behaviour"

BY

MR. F. A. ROVERS

Engineer, Hydrology Consultants Ltd.,
Mississauga

MR. J. P. NUNAN

President, Hydrology Consultants Ltd.,

DR. G. J. FARQUHAR

Associate Professor, Department of
Civil Engineering
University of Waterloo, Waterloo, Ont.



G. J. FARQUHAR

INTRODUCTION

In the past, sanitary landfilling of solid waste stood as an acceptable and frequently desirable means of disposal. Recently, its popularity has diminished for two significant reasons. First, there has been a movement away from the total discard philosophy toward the recovery of materials and energy from solid wastes. Second, there has been developed a somewhat negative public attitude toward sanitary landfills for several reasons, many of which can be related to inadequate design, operation and education.

Much is being done about the recovery and reclamation of materials and energy from solid wastes. The attractiveness of such proposals is obvious. However, recovery and reclamation does not yet represent a complete solution to the problem of solid waste management. In certain cases, lagging technology impedes implementation.

In others, a viable recovery and reclamation system does not appear to exist for some of the solid waste components and processing residues.

Negative public reaction due to unfavourable site aesthetics is regrettable since all of these conditions can be minimized or eliminated. The public can see and appreciate improved aesthetics. It is more difficult to demonstrate not only to the public but also to the regulatory authorities that the environmental impact of the disposal operation could be minimal.

The pollution of surface water and groundwater has been presented as an unavoidable consequence of sanitary landfilling. However, past experience has shown that water pollution does not, and need not, accompany landfilling in most cases. Where pollution has occurred the magnitude of the pollution has been confined locally and in many of these cases a control remedy can readily be implemented.

The pollution potential of solid waste disposal on land will be discussed in this paper by considering the following topics:

- 1) leachate production and characteristics,
- 2) the attenuation of leachate in the soil,
- 3) the control of leachate at waste disposal sites, and
- 4) leachate treatment.

It is to be noted that in this paper the term polluted water refers to the situation where the water has been altered in chemical quality to the degree that it is rendered nonpotable. A contaminated water refers to one which has been altered in chemical quality but one which remains potable.

LEACHATE PRODUCTION AND CHARACTERISTICS

An environmental impact assessment of waste disposal on land in a humid climate requires a working knowledge of the quantity and chemical character of the resultant leachate.

Leachate Production

The quantity of leachate produced at a waste disposal site can be estimated by field measurement and/or by the application of hydrogeologic principles.

Leachate is produced when the moisture content of the buried refuse reaches field capacity or saturation. Once field capacity is reached the production of leachate is equivalent to the net infiltration.

Factors controlling net infiltration at a completed landfill are the site size, cover slope soil and

vegetation character, hydrogeology and climatology. From an understanding of these factors and their interaction an estimate of the net infiltration equivalent to the leachate production can be made.

Remson et al (7) with data on the above factors were able to model the generation of leachate from a waste disposal site.

At Madison, Wisconsin, Reinhardt and Ham (1) measured a net infiltration rate of approximately 20 percent of the precipitation through covered refuse, with the cover sloped at approximately 3 percent.

In Illinois, Hughes et al (2) calculated leachate production rates of .52 to .68 gal/minute/acre at completed fills. It is to be noted that the infiltration rate was found to exceed one-half the annual rate of precipitation under the sandy soil conditions encountered.

Farquhar et al (3) estimated that at the St. Agatha, Ontario, landfill the average rate of leachate production was .28 gal/minute/acre.

Properly located and designed, Hydrology Consultants Limited (4) estimates that the rate of leachate production can be maintained below a rate of .15 gal/minute/acre.

Estimated values at numerous landfills range from .1 to .51 gal/minute/acre (4).

Leachate Characteristics

Leachate as a Source of Contamination

Investigations conducted by the University of Waterloo (3) demonstrated that the leachates examined at both the St. Agatha and the Brantford landfill sites were strong, potentially harmful liquids, capable of groundwater pollution. Certain of the leachate characteristics are presented in Table 1. Additional information on leachate strength published by other research workers was reviewed by Rovers and Farquhar (5). Several of these reports also dealt with strong, potentially hazardous leachates. Some of the maximum concentrations reported are shown in Table 2.

Notwithstanding the reduction in leachate strength and contaminant flux with time, as shown in Tables 1 and 3, the potential for groundwater pollution appears to exist for many years.

A comparison of contaminant discharge from 3 sources is presented in Table 4. The information is given in the units of lbs. of contaminant discharged per day. The data describing the final effluent and the digested sludge of the Waterloo Pollution Control Plant were collected

TABLE 1 LEACHATE STRENGTH VERSUS AGE OF SITE *

SOURCE	AVERAGE SITE AGE	CHARACTERISTIC						
		BOD ₅ (mg/l)	Cl (mg/l)	NH ₃ -N (mg/l)	HARDNESS as CaCO ₃ (mg/l)	PHENOLS ppb	SO ₄ (mg/l)	pH
FERGUS-ELORA	1 YEAR	13000	1000	180	3400	-	500	-
ST. AGATHA (LEACHATE POND INFLUENT)	4 YEARS	225	900	600	1400	200	10	7.3
BRANTFORD (WELLS 66 & 67)	9 YEARS	110	300	175	900	30	10	7.2
WATERLOO (WELL 504)	30 YEARS	2	96	10	772	4	-	7.5
UNCONTAMINATED GROUNDWATER (ST. AGATHA WELL 8)	-	10	3	0	120	6	-	8.0
FINAL EFFLUENT (WATERLOO PCP)	-	20	248	-	316	-	190	-
DOMESTIC SEWAGE TYPICAL DATA	-	200	250	25	300	-	200	7.5

* From Farquhar et al, (3)

TABLE 2

MEASURED LEACHATE CHARACTERISTICS
AT WASTE DISPOSAL SITES
SOME MAXIMUM VALUES REPORTED IN THE LITERATURE *

CHARACTERISTIC	CONCENTRATION (mg/l)
BOD (20 DAY)	54,610
TOTAL DISSOLVED SOLIDS	19,144
ALKALINITY (AS CaCO_3)	6,400
CHLORIDE (Cl)	3,500
CALCIUM (Ca)	690
TOTAL IRON (Fe)	5,500
MAGNESIUM (Mg)	249
ORGANIC NITROGEN (N)	260
AMMONIA NITROGEN (N)	440
SODIUM (Na)	900
SULPHATE (SO_4)	680

* Rovers and Farquhar (5)

TABLE 3

CONTAMINANT FLUX FROM LANDFILL *

SOURCE	REFUSE PLACED (TONS)	PER CAPITA PRODUCTION (LB/CAP/DAY)	CONTAMINANT	CONTAMINANT FLUX		
				(LB/YR)	(LB/YR/TON REFUSE)	(LB/YR/CAPITA)
<u>Brantford</u>						
Estimate 1	0.3×10^6	8	BOD	70	0.2×10^{-3}	0.3×10^{-3}
			NH ₃ -N	240	0.8×10^{-3}	1.2×10^{-3}
			CI	160	0.5×10^{-3}	0.8×10^{-3}
Estimate 2	0.3×10^6	8	BOD	650	2.3×10^{-3}	3.5×10^{-3}
			NH ₃ -N	410	1.4×10^{-3}	2.1×10^{-3}
			CI	1120	3.7×10^{-3}	5.5×10^{-3}
<u>St. Agatha</u>	0.45×10^6	15	BOD	9000	20×10^{-3}	54×10^{-3}
			NH ₃ -N	24000	53×10^{-3}	140×10^{-3}
			CI	36000	80×10^{-3}	220×10^{-3}
<u>Domestic Sewage</u>	-	-	BOD			16
			NH ₃ -N	-	-	7
			CI			15

* Farquhar, et al (3)

TABLE 4 CHEMICAL DISCHARGE TO THE ENVIRONMENT (LBS PER DAY)

CHARACTERISTIC	WATERLOO PCP FINAL EFFLUENT	WATERLOO PCP DIGESTER SLUDGE	WATERLOO OLD LANDFILL (3)
BOD ₅	1320	-	25
SODIUM	10080	4	78
CALCIUM	4980	46	20
MAGNESIUM	1560	5	27
CHLORIDE	14880	12	90
SULPHATE	11400	-	1
TOTAL KJELDAHL-N	270	50	99
TOTAL IRON	60	7.3	3.3
PHOSPHORUS	108	6.6	.5
CHROMIUM	-	.7	.02
NICKEL	-	.14	.07
LEAD	-	.23	N.D.*
CADMIUM	-	.02	N.D.*
ZINC	-	.92	.78

*N.D. - NOT DETECTED

in early May, 1974. The data on the old Waterloo Landfill are from the report by Farquhar et al (3). The site is the so-called St. Agatha site and the data were collected in 1971 at which time the average age of the site was 4 years. The information in the Table shows that the contaminant discharge in lbs/day from the digester sludge and from the landfill are quite similar. The discharges in the final effluent however are significantly larger. From this point of view therefore, the landfill does not represent a serious water pollution problem especially since the disposal of the digested sludge is also by means of direct application to the land.

Major Factors Affecting Leachate Strength

1. Refuse Composition

The composition of the refuse buried at a sanitary landfill site will determine the types of materials appearing in the leachate. While little information is available to relate leachate characteristics to the chemical composition of refuse, certain features seem apparent. The decomposition of most organic materials in refuse will yield to the leachate, soluble organic substances measurable as BOD, COD, volatile dissolved solids and organic nitrogen. Ammonia will be released as will dissolved carbon dioxide, both contributing to alkalinity. The metals calcium, magnesium, sodium and iron are common components of refuse and can be expected in high concentrations in leachate. Such is also the case for chloride, sulphate and carbonate ions. This is compatible with the information in Tables 1 and 2.

Although very little research has been conducted in this regard, it is likely that much of what enters the landfill as refuse eventually appears in the leachate, at least in the case of inorganic substances. The rate of release will depend on the rates of refuse decomposition and/or dissolution. The anticipation of leachate components, in addition to the expected ones, must be based on an analysis of the refuse. If materials such as pesticides and harmful heavy metals are eliminated from the buried material, they will not appear in the leachate.

2. Moisture Content

It has been found that the strength of leachate increases with increased moisture content of the refuse (5,9,10,11). A probable pattern of decomposition in response to changes in moisture content was identified. At low moisture content, aerobic conditions are possible. This will yield low concentrations of organic material in the leachate, a neutral to slightly alkaline pH and oxidized metallic ions encouraging the formation of insoluble precipitates. As the moisture content increases, anaerobic conditions develop. This will increase the soluble organic content of the leachate. The pH is likely to become acidic

and this, in conjunction with an increased organic content, will increase the solubility of many materials including metallic compounds.

Fungaroli (13) and Rovers and Farquhar (5) have shown that variances in infiltration rate will affect the concentration of chemicals in the leachate. Microbial "upsets" related to the influx changes in infiltration was postulated to account for the changes in leachate characteristics.

3. Site Age

Leachate strength tends to reduce with site age since materials within the refuse become depleted and because the more easily released materials are discharged first (12).

The data in Table 1, while somewhat scattered, show a definite pattern of dissipation in strength with time. The trend is also evident in data from Northeastern Illinois (6) presented in Figure 1.

It is not possible to determine how much of the refuse will appear as contaminants in the leachate. Much of the refuse has the potential for doing so; however, the time required for release is not known. Two features are apparent.

First, a large percentage of the organic material will be driven off as gas and water if biological decomposition takes place thus reducing the organic content of the leachate.

Second, a portion of the refuse will be released very slowly due to poor biodegradability and/or solubility. Plastics, some metals, and most non-metallic inorganic material such as concrete, brick, and plaster would be included here.

The results of six experiments conducted to examine contaminant release from buried refuse are summarized below in support of the foregoing discussion. The data are expressed as pounds of contaminant released per pound of refuse to provide some stable basis for comparison. Figure 2 shows the amount of leachate collected for each experiment. Experiments (C) and (D) consisted of field lysimeter studies in which moisture was added by natural precipitation. Experiments (A), (B) and (E) made use of laboratory lysimeters filled with refuse to which water was added artificially in amounts well in excess of the field additions. This latter was done to examine extremes in contaminant release. In experiments (B) through (E) leachate production occurred only after field capacity of the refuse had been reached.

Figures 3,4 and 5 display the release of chemical

FIGURE 1

Relationship Between Age of Refuse

and COD of Leachate

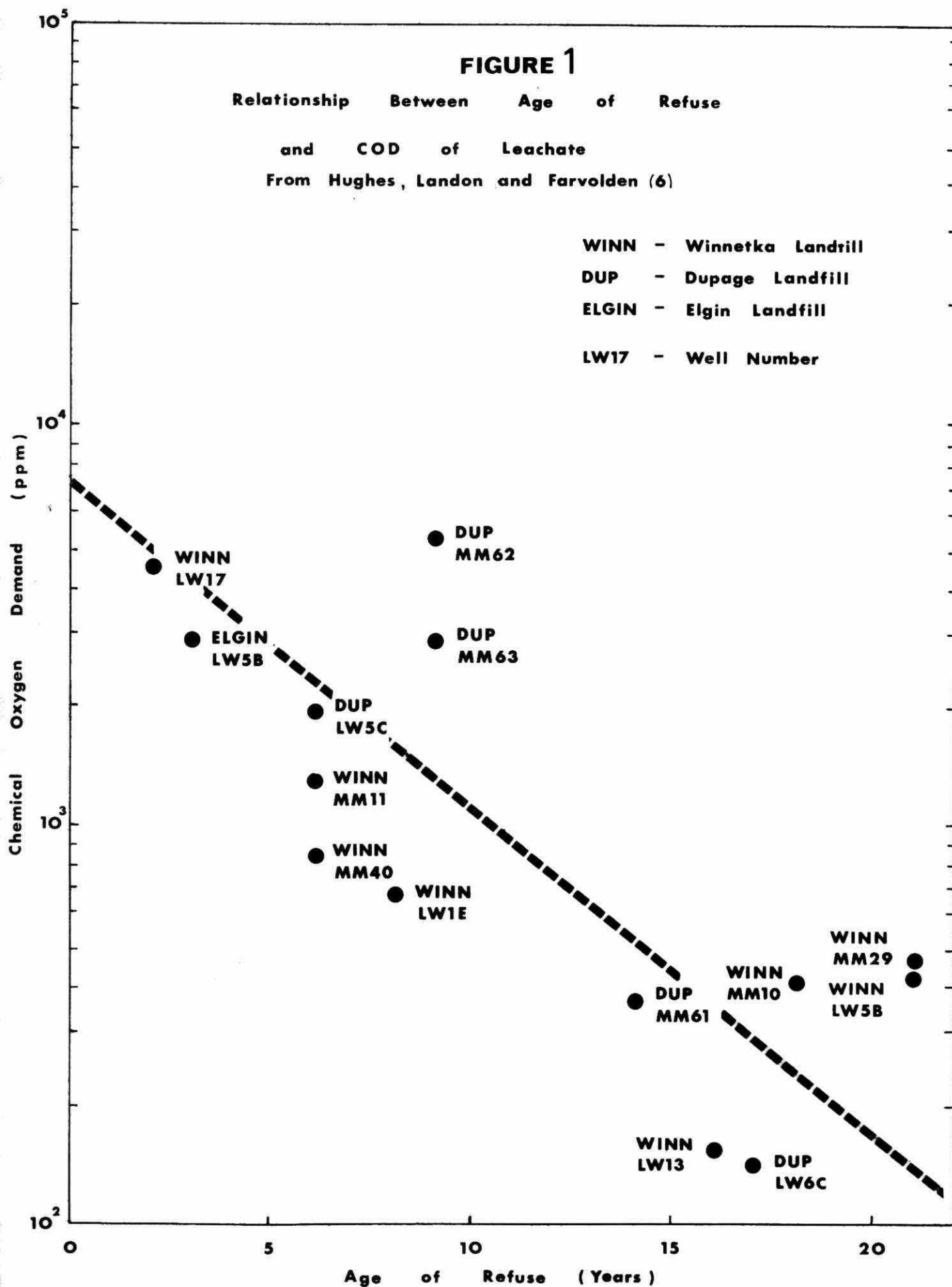
From Hughes, Landon and Farvolden (6)

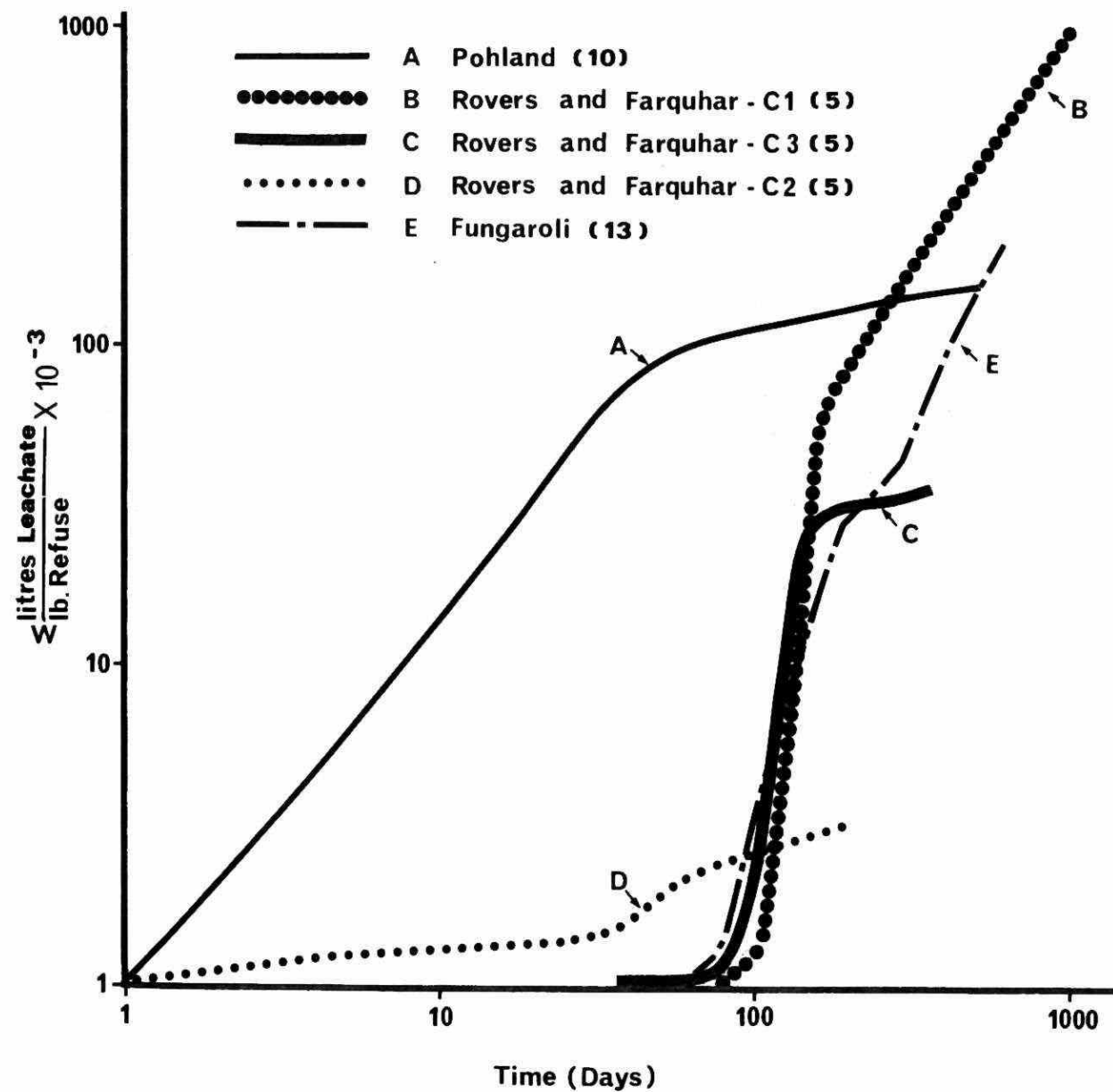
WINN - Winnetka Landrill

DUP - Dupage Landfill

ELGIN - Elgin Landfill

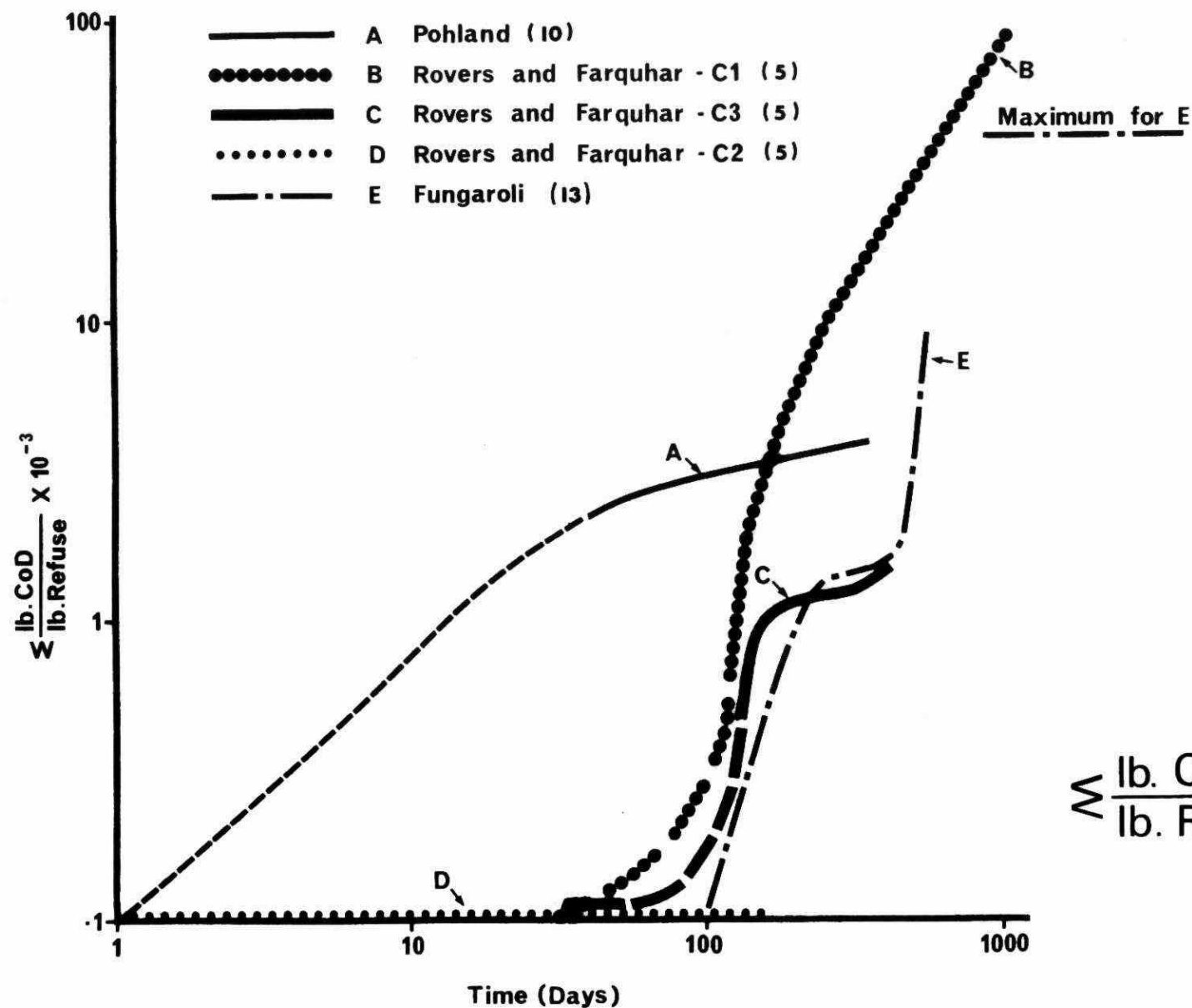
LW17 - Well Number





$\frac{\text{litres Infiltrate}}{\text{lb. Refuse}}$

FIGURE 2



$\Sigma \frac{\text{lb. CoD}}{\text{lb. Refuse}}$ vs Time

FIGURE 3

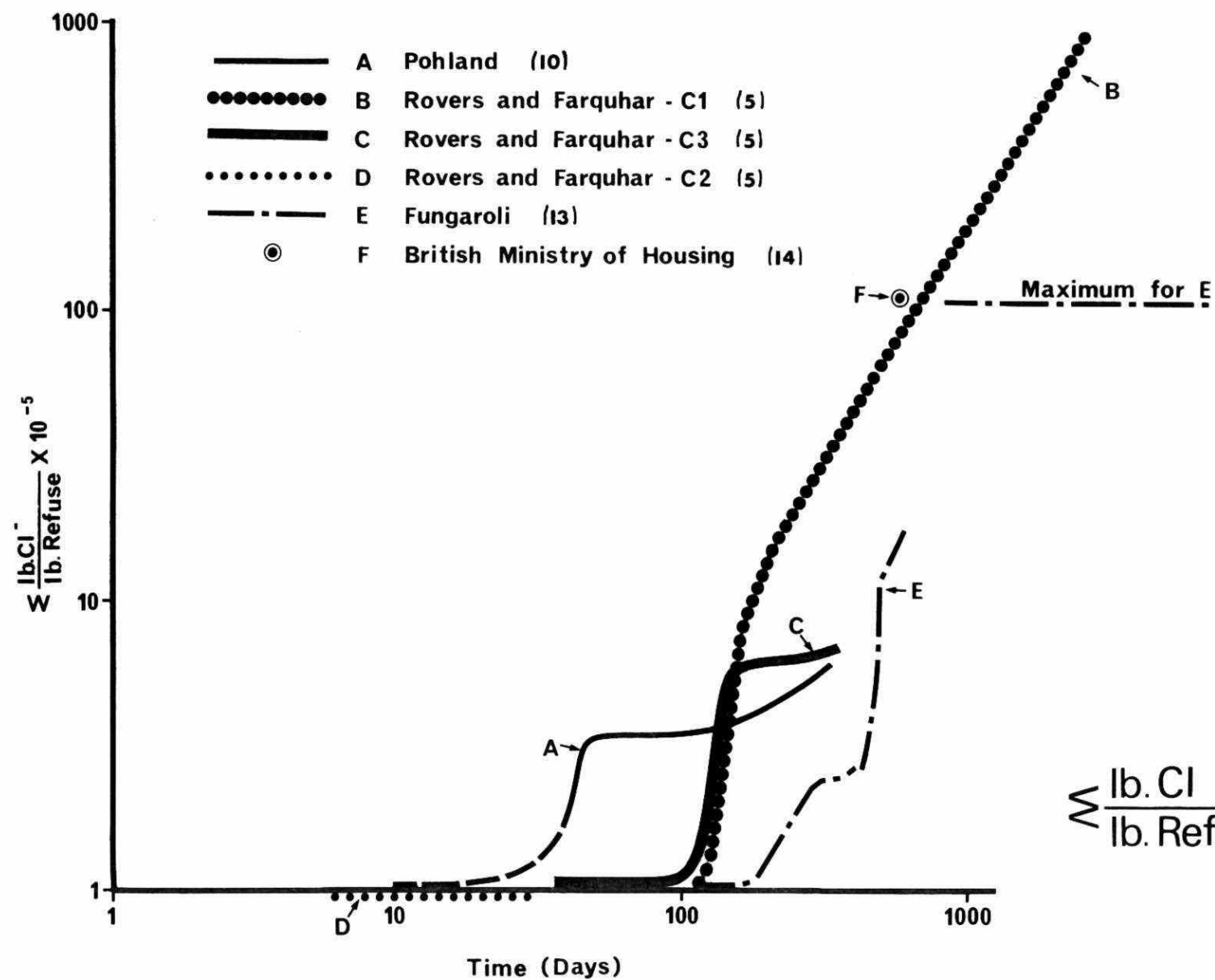
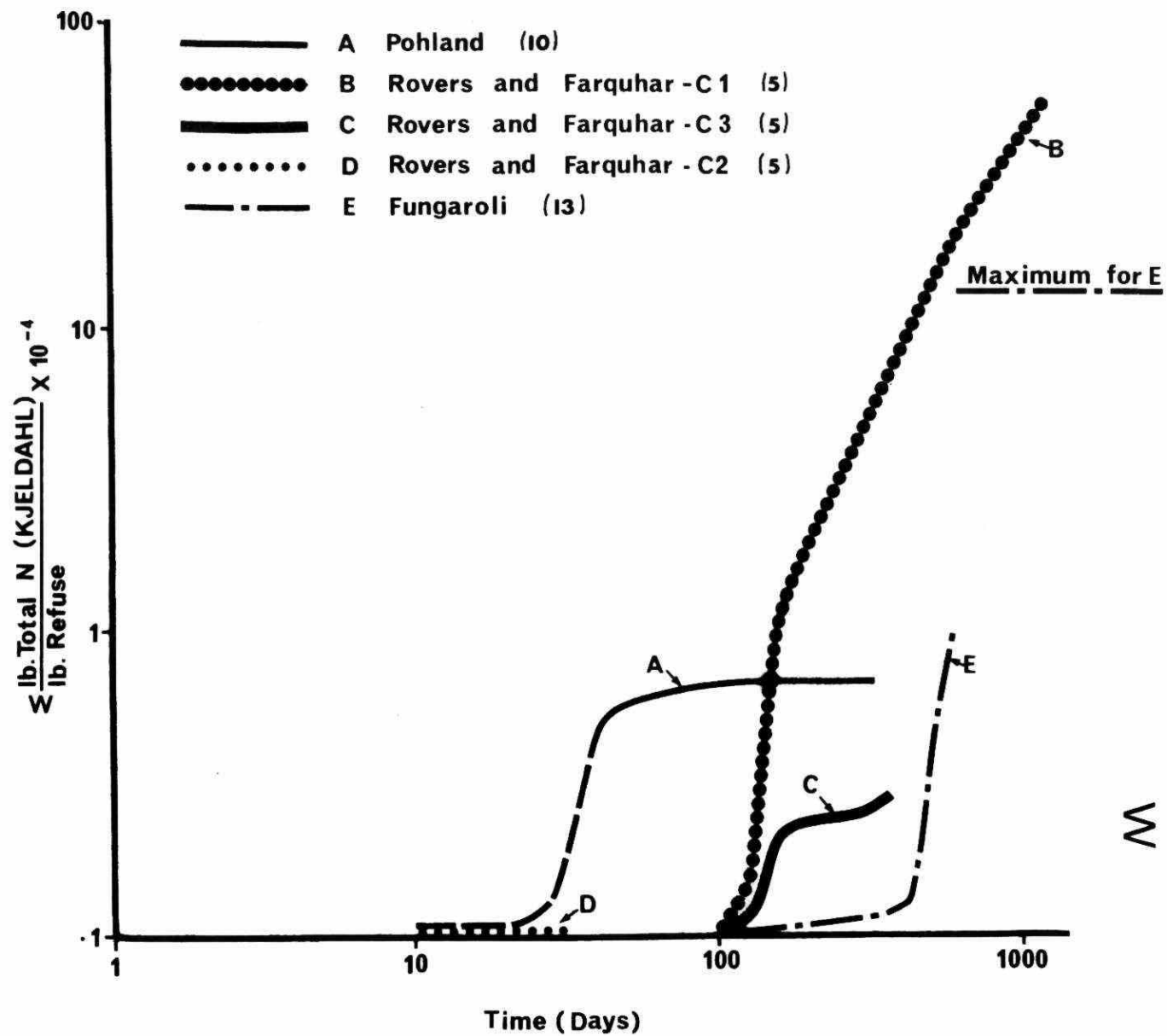


FIGURE 4



$\Sigma \frac{\text{lb. Total N}}{\text{lb. Refuse}}$ vs Time

FIGURE 5

oxygen demand (COD), chloride ion (Cl^-) and total Kjeldahl nitrogen (N). The data demonstrate that the release of contaminants was directly proportional to the amount of leachate produced and, thus, the amount of moisture added. This is most clearly the case for the COD results in Figure 3 where the production curves are of the same shape as the leachate production curves of Figure 2.

The release of chloride ion and total Kjeldahl nitrogen is shown in Figures 4 and 5 respectively. The data from experiments (B) and (C) display the same pattern as that described for COD. However, the release of these two materials in experiments (A) and (E) appears to have been retarded occurring somewhat more slowly than the COD release.

Experiment (D), a field lysimeter exposed to natural precipitation, was examined from late spring until early winter. Comparatively little precipitation infiltrated the refuse with little subsequent leachate production and virtually no contaminant release. The composition and refuse placement density of the experiments is shown in Table 5. These were identical in experiments (B) and (D), and very close to those of experiment (C). Thus, the only significant variable in these three experiments was the amount of moisture added. The differences in contaminant release between these experiments were therefore attributed to the differences in moisture addition. The chemical composition of the refuse was determined prior to placement in experiment (E). The results of these analyses are given below for the three contaminants used in this discussion.

COD	42.5×10^{-3} lb/lb dry refuse
chloride ion	97.0×10^{-5} lb/lb dry refuse
total Kjeldahl nitrogen	12.5×10^{-4} lb/lb dry refuse

These data can be used to define the maximum amount of each contaminant to be leached. They are shown as such on Figures 3, 4 and 5. A production of 10×10^{-3} lb COD/lb dry refuse or approximately 25% of the maximum leachable COD was achieved after 600 days of experimentation. In contrast, experiment (B) produced 91×10^{-3} lb COD/lb dry refuse in 1120 days. Table 5 provides a comparison between the refuse compositions of experiments (B) and (E). The readily decomposing organic materials include food wastes, grass clippings and leaves and it is likely that these would represent much of the COD. On a percent dry weight basis these are about twice as much in (B) as they are in (E). This would explain why the COD yield in (B) exceeds the maximum yield of experiment (E).

In order to manage contaminant production at a sanitary landfill site, it is important to know the amount and duration of contaminant release. The data from the 6

TABLE 5

PHYSICAL COMPOSITION OF REFUSE - % BY WEIGHT OF TOTAL REFUSE COLLECTED

PHYSICAL PROPERTY	POHLAND (10)	ROVERS & FARQUHAR (3)			FUNGAROLI (13)	M.H.L.G. (14)
	ARMENTROUT & BORTNER (11) (A)	C1 (B)	C2 & C3 (D)	(C)	(E)	(F)
Cans		5.97		3.5		2.7
Ferrous Metals	4.0	0.5		3.6	6.86	
Non-Ferrous Metals		.99		0.8		
Glass	7.0	12.05		6.9	7.73	8.5
Brick, Stones	5.0	0.16		13.5		42.7
Dirt, Ashes					2.29	
Food Wastes	25.0	34.89		31.6	8.4	18.53
Grass Clippings, Leaves					6.88	
Wood Limbs, Sawdust	1.0	1.11		5.9	2.29	
Plastics	3.0	3.17		4.5	0.76	
Leather, Rubber					0.76	
Rags	5.0	1.62		3.8	0.76	2.3
Paper	50.0	40.0		25.8	53.46	16.7
Miscellaneous					9.81	5.0
Weight per cell (lbs)	1400.0	6000.0		C2-6000.0 C3-1482.0	3500.0	215200.0
Compaction density (lbs/yd ³)	535.0	570.0		C2-583.0 C3-530.0	327.0	864.0
Classification *	wet no recycle	wet		C2- dry C3- wet	wet	wet

* wet: high moisture content representative of refuse deposited within groundwater table
dry: low moisture content representative of refuse deposited above groundwater table

experiments are incomplete in this regard. However, they demonstrate that under the conditions of moisture addition in the field, contaminant release is a slow process. The data also suggest that, at least for some of the more readily released materials, a large percentage of the material placed will appear in the leachate.

CONTAMINANT MIGRATION IN THE ENVIRONMENT

Directed by a gradient, leachate discharging from a landfill could move through the receiving environment as follows:

- 1) through the zone of aeration to the water table
- 2) through the zone of saturation to a discharge area such as a stream
- 3) through the stream to the sea.

The flow pattern of leachate in the zone of saturation is controlled by the hydrogeologic conditions in the vicinity of the landfill site. If the landfill is located in a groundwater recharge area, the flow path will be directed toward some groundwater discharge zone such as a stream or lake. Shortcircuiting of the regional flow system is often manifest by "leachate" springs near the perimeter of a landfill. The operation of production wells near the site could also cause a shortcircuiting of the natural flow pattern.

Contaminants contained in the leachate are attenuated to varying degrees as they migrate through the groundwater regime. The processes of attenuation which lessen in severity or dilute contaminants include:

- 1) dilution, dispersion or diffusion
- 2) mechanical filtration
- 3) gaseous exchange
- 4) sorption
- 5) chemical precipitation and co-precipitation
- 6) microbial activity.

The general processes of contaminant attenuation describe complex physical, biochemical and chemical relationships which to-date defy quantitative definition. However, the quantitative prediction of contaminant levels discharged to the environment are being requested by the courts and regulatory agencies (8,18).

Empirical Predictions

The limited monitoring of ground and surface waters at landfills and the expert observation of many others has determined that leachate migration from a landfill site will effect a limited zone of polluted water. It is to be noted that a landfill will pollute the environment to some extent.

The intergranular flow of leachate through fine textured materials from fine sands to clay will effectively limit the zone of pollution from a landfill. In coarse materials such as coarse sands and gravels the zone of pollution can be extensive. Where the leachate moves through cracks or fissures, leachate migration and attendant pollution can extend over many thousands of feet. Generally these observations have been found to be applicable to liquid waste disposal on land.

It is proposed that the above observations coupled with a hydrogeologic site investigation and monitoring data of a geologically similar site can be used to empirically predict the contaminant migration from a proposed disposal site.

Tables 6,7,8,9 and 10 respectively, demonstrate the attenuation of leachate through fine silty sand, clay till, fine sand, till and sand and fine to medium sand. The data in the tables represent landfills of varying age, refuse depth, site size and type of waste disposed.

Table 6 demonstrates that leachate from a 9 year old landfill which accepted both liquid, industrial and municipal waste in the past is attenuated within 700 feet downgradient.

Table 7 shows that contaminant migration downgradient of the site is attenuated to a significant degree in 10 feet of movement through the zone of aeration. Within 100 feet of groundwater quality is comparable to the base quality. It is worthy of note that at the Old Waterloo landfill a leachate collector and treatment lagoon was installed which has actually increased the environmental impact. The lagoon does not treat the leachate effectively and, as a result, significant stream pollution has occurred at the point of discharge.

The "old" Disposal Services landfill in Maple, Ontario, has received, over the past 20 years, an assortment of liquid and solid waste generated in the Metropolitan Toronto area. The refuse extends to depths of 150 feet over an area approximately 40 acres. It has been postulated by many that extensive groundwater pollution must have occurred as the soil consists of fine sands with the base of the site lying within 10 feet of the water table.

Table 8 shows that within 800 feet downgradient of the landfill, the groundwater is potable. Within 2000 feet, the groundwater quality compares with the base quality.

Table 9 presents attenuation data at the York Sanitation Company Limited site #4, Town of Whitchurch-Stouffville. Over the past fifteen years the site has accepted all types of waste, with the bulk of the waste being solid and liquid industrial waste. In the 1960's many millions of gallons of liquid industrial waste were

TABLE 6 *

BRANTFORD
SOIL-FINE SILTY SAND

CHEMICAL CHARACTERISTICS	SAMPLE POINT		
	LEACHATE	200' SOUTH OF FILL	700' SOUTH OF FILL
AMMONIA NITROGEN (N)	175	60	1.0
ORGANIC NITROGEN (N)	125	25	10.0
CHLORIDE (Cl)	350	350	20
PHOSPHORUS (P)	6.0	.6	-
PHENOLS ppb	30	12	0
HARDNESS (AS CaCO_3)	900	850	500
BOD_5	200	30	5
CALCIUM (Ca)	156	215	153
MAGNESIUM (Mg)	122	77	25

AVERAGE REFUSE AGE - 9 YEARS

* Farquhar et al, (3)

TABLE 7*

OLD WATERLOO LANDFILL

SOIL-CLAY-TILL

CHEMICAL CHARACTERISTICS	SAMPLE POINT			
	LEACHATE	10' BENEATH REFUSE	100' EAST OF FILL	BASE QUALITY
AMMONIA NITROGEN (N)	600	40	0.5	0.2
ORGANIC NITROGEN (N)	300	60	1.0	0.4
CHLORIDE (Cl)	900	250	20.0	4.0
IRON (Fe)	50	25	0.5	0.5
PHOSPHORUS (P)	4.5	4.0	.05	.06
PHENOLS - ppb	200	150	8.0	8.0
HARDNESS (AS CaCO_3)	1400	700	250	140
BOD ₅	250	150	5	4
CALCIUM (Ca)	156	100	40	25
MAGNESIUM (Mg)	249	120	37	19
IRON (Fe)	35	15	.8	.7
pH	7.2	7.2	7.6	7.7

AGE OF SITE - 10 YEARS

* Farquhar et al, (3)

TABLE 8*

DISPOSAL SERVICES - MAPLE

SOIL - FINE SAND

CHEMICAL CHARACTERISTICS	SAMPLE POINT			
	150' SOUTH OF SITE	800' SOUTH OF SITE	2000' SOUTH OF SITE	BASE QUALITY
CHLORIDE (Cl)	252	132	10	5
IRON (Fe)	2.5	.2	.3	.2
SODIUM (Na)	4.3	3.5	7.0	1.7
POTASSIUM (K)	0.4	0.1	2.0	0.1
HARDNESS (AS CaCO_3)	414	503	285	301
ALKALINITY (AS CaCO_3)	220	432	252	-
ZINC (Zn)	.08	0.38	.06	.17
CALCIUM (Ca)	100	147	91	87
MAGNESIUM (Mg)	40	33	14	20
COD	131	83	--	--

AGE OF SITE - 20 YEARS

* Hydrology Consultants Limited (19)

TABLE 9*

YORK SANITATION-WHITCHURCH-STOUFFVILLE
TILL UNDERLAIN BY SAND AQUIFER

CHEMICAL CHARACTERISTICS	SAMPLE POINT				BASE QUALITY
	MOVEMENT THROUGH TILL FROM LAGOON		MOVEMENT THROUGH SAND AQUIFER FROM LAGOON		
	15'	125'	150'	600'	
HARDNESS (AS CaCO ₃)	2840	640	23	340	228
ALKALINITY (AS CaCO ₃)	684	467	306	220	229
CHLORIDE (Cl)	72	46	28	19	2
pH	7.0	7.1	10.0	7.1	7.6
PHENOLS ppb	30	20	600	< 6	2
SULPHATE (SO ₄)	2040	207	79	70	20
IRON (Fe Diss)	.15	.10	.30	< .02	.10
CHROMIUM (Cr Tot)	< 0.1	< 0.1	< 0.1	< 0.1	0.0
COPPER (Cu)	12.0	.88	.67	< .02	0.0

AGE OF SITE - 15 YEARS

* Hydrology Consultants Limited, (20)

TABLE 10*

YORK SANITATION - WEST GWILLIMBURY

FINE TO MEDIUM SAND

CHEMICAL CHARACTERISTICS	SAMPLE POINT			
	POTATO WASTE	200' WEST OF SITE	700' WEST OF SITE	BASE QUALITY
CHLORIDE (CI)	-	-	26.0	9.0
AMMONIA NITROGEN (N)	515.2	0.0	0.0	0.0
ORGANIC NITROGEN (N)	1125.6	11.2	5.6	5.6
ALKALINITY (AS CaCO_3)	-	3000	240	204
HARDNESS (AS CaCO_3)	-	-	290	240
COD	93436	-	24	-
pH	6.7	6.9	7.8	7.2

* Hydrology Consultants Limited

dumped at the site. The liquid waste included acid, caustic and oil wastes.

Table 9 shows that migrating liquid wastes from the lagoons showed a marked improvement in quality after moving 125 feet through a till deposit. Test holes near the lagoon showed the till contained numerous sandy lenses which would reduce the degree of attenuation indicative of the till. The chemical characteristic of the lagooned waste includes a pH greater than II and a phenol content greater than 5000 ppb.

The migration of similar liquid wastes was also monitored in an extensive groundwater aquifer beneath the site. The groundwater differed slightly from the background in an observation well located 600 feet south of the lagoon. Attenuation in the aquifer sands was significant.

An on-site domestic well located 900 feet down-gradient from the waste lagoons has remained unaltered in quality.

Table 10 shows that liquid potato waste lagooned at the York Sanitation Company Limited site in West Gwillimbury was effectively treated in moving through 700 feet of fine to medium sand.

The above examples clearly show that, with proper site selection, the soil will effectively treat migrating pollutants from a waste disposal site.

The above data which demonstrates the attenuation ability of various hydrogeologic environments can be used to estimate the contaminant migration pattern from proposed disposal sites.

It was in this manner that Hydrology Consultants Limited (18) was able to estimate the quality of groundwater discharge to local streams for the proposed C-P Railway site at Port Hope, Ontario. The character of the leachate is presented in Table 11.

The above empirical modelling has a deficiency in that the soil characteristics for the various sites defining the model are poorly defined. The clay and silt size fraction of the soil participate most strongly in the attenuation of contaminants. Similarly the cation exchange capacity and the organic content of the soil has been correlated to the attenuation ability of the soil. (12).

The empirical prediction of contaminant migration in the soil would be improved if the monitored site soil characteristics were to be more clearly defined.

Semi-Quantitative and Quantitative Predictions

Research is presently being sponsored by the Environmental Protection Agency, in the U.S.A., the Ontario

TABLE 11*

ESTIMATED CHARACTER
OF LEACHATE DISCHARGE TO STREAM -
PORT HOPE

300' MOVEMENT THROUGH SILTY SAND	
CHARACTERISTIC	DISCHARGE CONCENTRATION (mg/l)
CHLORIDE (Cl)	140
HARDNESS (AS CaCO_3)	250
BOD ₅	10-20
TOTAL DISSOLVED SOLIDS	450

* Hydrology Consultants Limited (18)

Ministry of the Environment and by Environment Canada for the development of predictive models describing contaminant migration through the soil.

Research is actively underway at the University of Waterloo, Waterloo, Ontario, the University of Arizona, Arizona, U.S.A. and the Illinois State Geological Survey, Illinois, U.S.A. The U.S. Environmental Protection Agency will sponsor further work in the future. An exchange of information related to pertinent research programs is currently taking place between Canadian and American researchers and project directors under the auspices of Environment Canada.

To-date, mathematical prediction models do not exist. However, these should become available within a few years.

At this time, the alternative to accepting an empirically based environmental impact assessment of a proposed waste disposal site is to collect all generated leachate for treatment.

CONTROL OF LEACHATE AT WASTE DISPOSAL SITES

The prime objective of leachate control is to prevent, or at least greatly reduce, the flux of landfill-produced contamination to the groundwater and/or surface water regimes. As discussed earlier in this paper, many types of soil have an ability to attenuate waste residues and thus reduce the contaminant flux to the hydrologic system. Where possible this natural ability of the soil to treat leachate should be employed. It is by far the simplest and cheapest method of leachate control. Many fine grained moderately to poorly permeable silt and clay rich soils offer excellent potential for natural control of landfill-produced contamination. Favourable hydro-geologic environments where such soils occur can usually be found.

The driving force for groundwater movement is gravity, the direction of movement being a function of pressure and elevation. The slope of the water table indicates the general direction of leachate movement. The actual path may be influenced by other factors such as variations and/or stratification of earth materials, the topography and elevation of the top of the zone of saturation and by external factors such as streams that intercept the water table and/or pumping wells. The third dimension, the vertical component of flow must always be considered. Close to streams that receive groundwater discharge there may be an upward movement of groundwater. In such areas, the natural flow system controls the movement of leachate - extensive groundwater pollution is prevented but undesirable quantities of contaminants may reach the stream.

There are several methods of controlling landfill produced leachate and the pollution that can result

there from should the natural control through soil attenuation, as discussed above, be deemed unacceptable because of poor definition.

The quantity of leachate produced and thus the amount requiring treatment after collection, can be greatly reduced by careful site design and good management. Recent studies such as those carried out by Ham and his associates at the University of Wisconsin (1) indicate that approximately 20 percent of the annual precipitation, or roughly six inches will infiltrate compacted refuse and become leachate in our climate. By using a thick final cover of clayey soil, graded to relatively steep slopes, it may be possible to reduce the production of leachate to about 3 to 4 inches per year. This is equivalent to an average production rate of roughly 0.15 gpm/acre of landfill. The ultimate would be to eliminate infiltration into the landfill by a surface liner.

Where the soil conditions are unsuitable, or the travel distance too short before discharge, for natural treatment, waste may be deposited upon essentially impermeable in-situ soil or bedrock where careful bottom grading directs leachate along the bottom of the fill to suitable collection facilities that transfer the polluted water to a treatment facility. This is the method of control employed at the new Town of Halton Hills (Georgetown) Ontario site. With adequate surface drainage control and good site management, the amount of leachate collected by this method should not exceed about 0.3 gpm/acre of landfill. The quantity can fluctuate greatly if surface site drainage is not adequately controlled.

A third method of control utilizes the natural groundwater flow system. Here, since leachate cannot go down because of the upward component of groundwater movement, it must move laterally to discharge with the groundwater. If not intercepted, this leachate can pollute small receiving streams. It appears that this method of control should only be employed where the refuse disposal area comprises a major portion of a stream drainage basin above the point where leachate is produced and discharged. The leachate from a site of this type can be collected for treatment by intercepting all groundwater and surface water immediately downstream from the disposal site or, alternatively, by installing an infiltration gallery between the landfill and the receiving stream. The leachate interceptor must be installed well below the normal water table to ensure that it will not be above that zone during dry periods. It must be remembered that the water table can, and often does, change either up or down due to the filling operation.

Manipulation of the normal flow path of groundwater and the use of leachate interceptor tiles is the method used to control leachate migration at the Barrie, Ontario, and Metro Toronto, Beare Road sites. Leachate

flows collected in this manner because of groundwater dilution can be significantly greater than the same situation where the undiluted leachate is collected.

The pattern of underground movement of leachate can be readily determined by measuring the fluid potential in the ground through observation wells. The concentration of contaminants and their pattern of dispersion is monitored by sampling water from the observation wells. Should the pattern of subsurface contaminant migration be in variance with what is desirable, it can be altered by lowering the water table at strategic points. This can be done through the use of pumping wells or by the installation of drainage tiles. Drainage tiles are to be preferred over wells. Although the capital cost of installing tiles may be greater, they avoid the problems and cost inherent in the operation of a mechanical system. At Barrie, Ontario, a backup installation of wells was proposed to control leachate movement should the groundwater regime at the site change thereby making the infiltration gallery ineffective.

In recent years public concern over the pollution potential of landfill produced leachate has grown tremendously. This concern is apparently out of all proportion to the real hazard if we are to judge from past history. Very few problems related to leachate migration have arisen where practically no precaution whatever has been taken. As a result of this concern, and because of the difficulty in procuring the most desirable sites for landfill, there has been an increasing interest in the use of impermeable membranes or liners that will intercept leachate at the base of buried refuse and thus prevent it from entering the soil beneath the landfill site. Leachate thus intercepted must be collected and removed for treatment before release into the environment. A liner can be employed so as to utilize land for solid waste disposal that otherwise may be unsuitable from a hydrogeologic viewpoint. A liner of suitable material, carefully installed beneath the entire fill area is, in theory at least, a positive method of leachate control.

A landfill liner to be effective must shed most of the infiltration-become-leachate that impinges upon it and should retain its impermeable characteristics for several decades. Factors that could affect leakage through a liner and the pattern of leachate discharge from a collector system include the following:

- rate of infiltration, which can be controlled by cover and grading;
- seasonal fluctuation in rate of infiltration;
- damping caused by travel of infiltrate through refuse;
- areal pattern of infiltration;
- liner permeability;
- fluid head above the liner;
- rate of shedding from liner, which can be controlled by smoothness, bottom contours, and spacing of collector tiles.

It is possible to predict the amount of leakage through a liner using basic assumptions and fundamental hydrologic principles. Calculations show that the bottom grades and tile spacing do not affect significantly the amount of leakage through a liner with permeability lower than about 10^{-8} cm/sec. These factors could affect leakage through more permeable liners. Calculations were made based upon an assumed annual infiltration rate of 16 cm (6.3 inches) with peak rates during the spring up to 0.8 cm/week, diminishing to less than 0.1 cm/week in late summer and early fall, and then rising again to about 0.3 cm/week in late fall. These calculations show the effect of different liner permeabilities. A liner with permeability 10^{-8} cm/sec will shed essentially all 16 cm of infiltration. A permeability of 10^{-7} cm/sec sheds 75 percent of the infiltration and allows 25 percent to pass through. Only 10 percent of the leachate is shed by a 10^{-6} cm/sec permeability with 90 percent leakage. All 16 cm will theoretically penetrate a relatively flat liner with permeability 10^{-5} cm/sec.

Figure 6 graphically shows the performance of a liner with a permeability of 10^{-7} cm/sec.

Table 12 presents the data on liner performance with a permeability varying from 10^{-5} to 10^{-8} cm/sec. Table 12 shows that except for a permeability of 10^{-8} cm/sec the liners would allow a portion of the produced leachate to discharge to the environment.

Many different materials have been and are used to line liquid waste storage lagoons and fluid reservoirs. These materials include polyethylene, polyvinyl chloride, asphalt, cement, rubber and various types of clays. Some of these may be useful for constructing solid waste disposal site liners and have been proposed for that purpose. The synthetic materials, which are byproducts of the petroleum industry are expensive and increasingly difficult to obtain. They are essentially impermeable when carefully installed. Unfortunately, their integrity against the effects of leachate over long periods has not been proven. The manufacturers' guarantees for plastic and thin rubber membranes are not as long as the expected duration of leachate production, which may extend over several decades. Also membrane materials are subject to rupture by heavy equipment and could be difficult to place effectively on a piece-meal basis over the large areas now required for sanitary landfill.

Even though many of the synthetic materials may be effective, proof of their suitability requires further study. This is currently being undertaken under the auspices of the U.S. Environmental Protection Agency.

Numerous laboratory permeability tests on silt and clay rich glacial tills from many areas around Metro Toronto have produced "k" values in the range of 10^{-8} to 10^{-4} cm/sec. Rarely, however, does local till even when

LINER PERFORMANCE

FIGURE 6

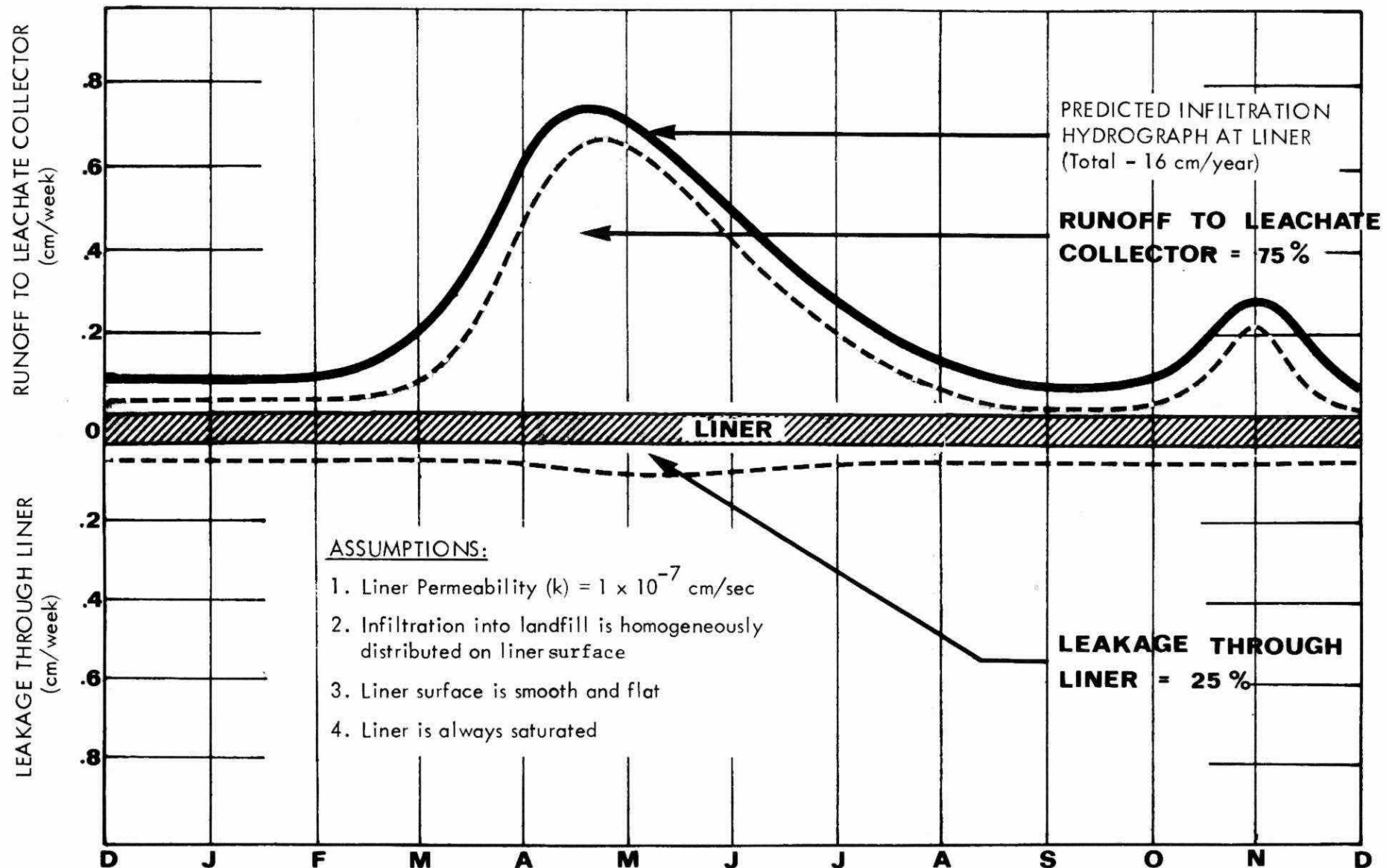


TABLE 12
LINER PERFORMANCE *

LINER PERMEABILITY CM/SEC	PER CENT RUNOFF	PER CENT LEAKAGE
1×10^{-5}	0	100
1×10^{-6}	10	90
1×10^{-7}	75	25
1×10^{-8}	98	2

* ASSUMPTIONS LISTED ON FIGURE 6

remolded and compacted to high density in the laboratory yield permeability values less than 10^{-7} cm/sec.

Sodium montmorillonite (bentonite) and other relatively pure clays have proven effective in reducing soil permeability to the degree required for an effective sanitary landfill liner. Bentonite, which swells to many times its dry volume when wetted with water is commonly used to create an impermeable liner. Tests performed by Hydrology Consultants Limited and by others show that bentonite mixed with fine sand at a ratio of 1:20 can be used to produce permeabilities in the order of 10^{-8} to 5×10^{-8} cm/sec. There is evidence, however, that bentonite reacts chemically with leachate and loses some of its swelling properties. The tests conducted by Hydrology Consultants Limited on behalf of Metro Toronto in connection with the installation of a liner at the proposed Liverpool Road landfill show that three percent mixes of different grades of bentonite and fine sand increased in permeability by approximately one order of magnitude when leachate was passed through them for a period of several months. Figure 7 graphically details the performance of the sand-bentonite liner under the infiltration of leachate. This suggests that bentonite may have certain limitations as a landfill liner material, and indicates that further testing is advisable. Non-swelling, relatively pure illite-type clay could be considered as an alternative to bentonite. Its use would require installation of a thinner liner if costs were to be comparable.

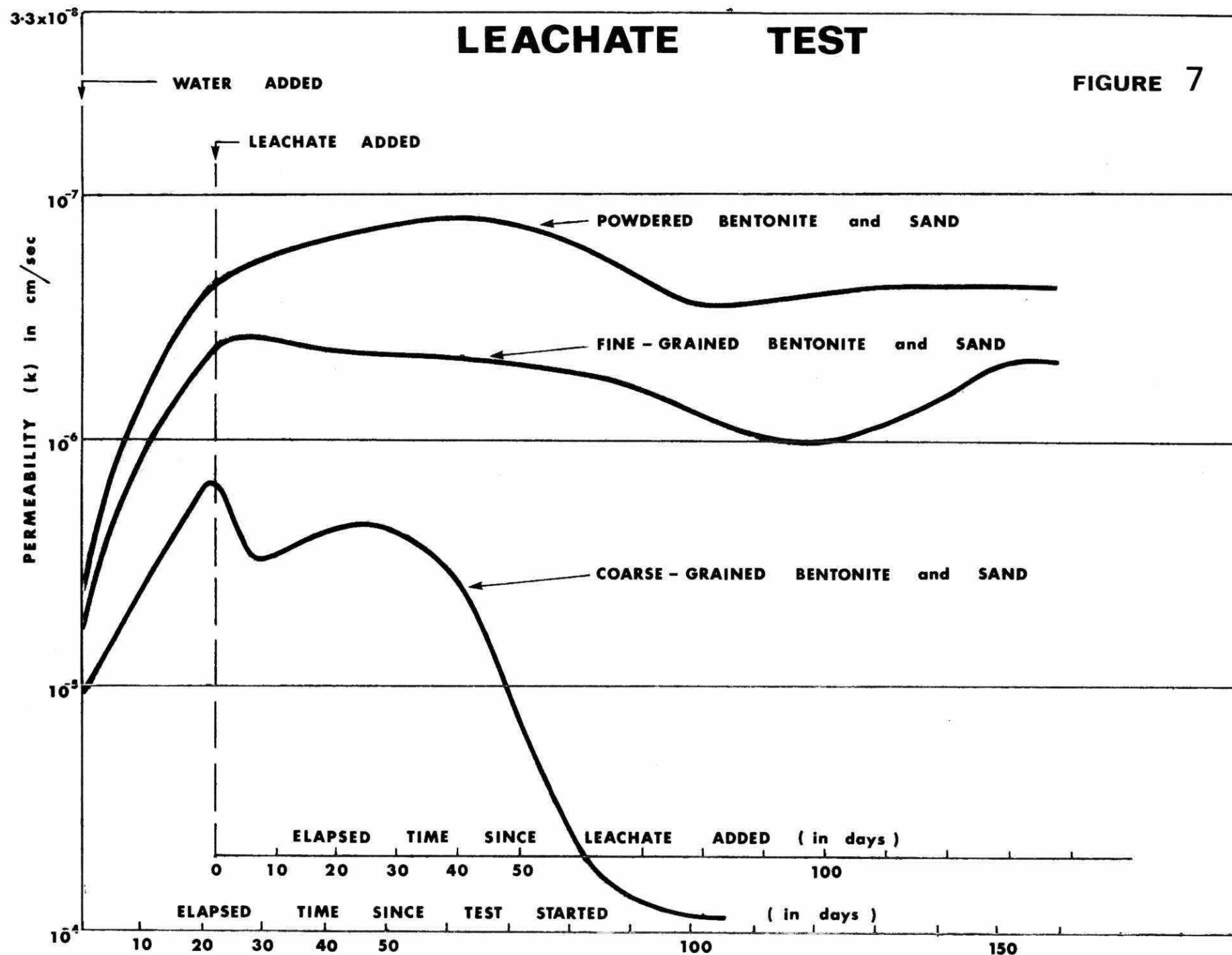
In 1972 the E.P.A. screened 28 substances for use in a future test program (22). Of the 28 substances used in the initial program, only bentonite performed satisfactorily.

Mannian (23) tested 29 sealant materials of which clay (Zeogel) performed most satisfactorily. Of the landfill sealant materials the bentonite at a cost of 800 dollars per acre was significantly cheaper. The next cheapest landfill sealant was costed at \$11,600 per acre.

In October 1973, Materials Research and Development a Division of Woodward-Lundgren and Associates, California, U.S.A., prepared preliminary installed costs of potential liners. Again, the soil-bentonite (Volclay) liner performed more cheaply at a cost of \$1.17 per square yard at an application rate of 2 lbs per square foot.

LEACHATE TREATMENT

As a means of circumventing the potential for groundwater contamination, much discussion has been directed at the subject of landfill leachate collection and treatment. Three significant pieces of research have been conducted in order to examine on-site leachate treatability. The results of these studies are summarized below.



The studies of Boyle and Ham (15) and of Foree and Reid (16) were quite similar in scope and reached essentially the same conclusions. Both found that anaerobic biological treatment could perform satisfactorily. Boyle and Ham observed greater than 90% COD removal for initial COD's ranging from 2000 to 22000 mg/l. Foree and Reid achieved 95% COD reduction from an initial concentration of 12700 mg/l during 20 days of anaerobic treatment. The latter researchers also examined the polishing of the effluent from the anaerobic treatment process. Using a mixture of lime and activated carbon, the residual COD was reduced by 80%, leaving the effluent with a COD of approximately 90 mg/l.

Spencer (17) studied the treatment of leachate by means of aerobic biological decomposition in the context of extended aeration. The initial COD ranged from 8000 to 12000 mg/l. The mean hydraulic residence time was on the order of 10 days with a mixed liquor suspended solids concentrations between 2500 and 5500 mg/l. Several experiments were conducted and the COD removal efficiency ranged from 95 to 97%. The leachate was found to be phosphorus deficient and supplementation was necessary. Design parameters and unit costs were developed. Effluent polishing was also examined and activated carbon was found to reduce the COD in the biologically-treated effluent by approximately 80%, leaving an effluent COD on the order of 40 mg/l.

In addition to excellent removal of COD, Spencer also found that aerobic treatment accomplished in excess of 95% conversion of NH_3 and organic nitrogen from concentrations of 300 and 160 mg/l respectively. Major reductions were also achieved for many metallic ions. Effluent suspended solids concentration were on the order of 100 to 150 for most experiments. These were removed in excess of 95% by means of filtration.

Both Boyle and Ham (15) and Spencer (17) examined the treatment of raw leachate by chemical means. In neither case was satisfactory treatment achieved. Boyle and Ham used oxidants, precipitants and coagulants with a maximum COD removal of 25%. Spencer used aeration, precipitants and coagulants, both organic and inorganic, and achieved no greater than 10% removal of COD with any of the procedures.

It is apparent that biological treatment, either aerobic or anaerobic, followed by tertiary treatment using filtration and activated carbon provides a suitable treatment system for landfill leachate. The COD concentrations in the experiments described ranged from 2000 to 22000 mg/l. However, landfill leachate COD's may reach 3 to 4 times this range in the initial years after placement. Treatment at these concentrations has not been examined in detail. In many cases dilution prior to treatment would be reasonable because of the small flows involved. Toxicity

was not a problem in the experiments described. However, it could become a problem at sites receiving large volumes of toxic materials for disposal.

If the leachate can be directed to a sanitary sewer treatment would be facilitated in the PCP. In the situation where the landfill serves the same community serviced by the PCP adverse effects on the treatment provided at the sewage would be minimal as the relative flow of leachate to sewage would be very small. However, if a major centre were to dispose of its waste in a small community the enlarged landfill and subsequent enlarged leachate flow could seriously hamper the sewage treatment operation should the leachate be added to the community flow. Boyle and Ham (24) have shown that 10 percent by volume leachate addition to the activated sludge process will upset the treatment process.

A final leachate treatment process is provided by recycling of leachate through the refuse as proposed by Pohland and Maye (25). The treatment provided in this manner seems to be effective. However, the mechanics of operation have not been defined. It is postulated that these could limit the use of recycle as a leachate treatment alternative.

SUMMARY AND CONCLUSIONS

A. The few North American waste disposal sites, that have been assessed in the last decade for their environmental impact, indicate that the production and character of landfill-produced leachates are not readily predictable. However, the following observations can be made:

- i) Once refuse attains a moisture content equal to the field capacity, leachate production becomes equivalent to the net infiltration. The observed and calculated average net infiltration rates vary from 0.1 to 0.68 gal/minute/acre and are a function of the site hydrogeology, topography and climatology.
- ii) The yearly dissolved and suspended contaminant loading to the environment by a landfill is significantly less than the loading by a pollution control plant where both serve the same population.
- iii) The major factors affecting leachate character and strength are refuse composition, rate of infiltration and site age. The refuse composition determines the chemical character of the leachate. The chemical character of the leachate is limited to the composition of the disposed refuse. The leachate strength is a function of infiltration rate, site age and refuse composition.

tion. Seasonal variations in infiltration rate affect the leachate strength. This effect is most significant at landfills where the depth of waste is shallow.

It would appear that the dissipation of leachate strength is a function of infiltration rate and site age.

- iv) It is postulated that most of the inorganics disposed of in the soil will be leached to the environment. The rate of leaching and simultaneous microbial activity will affect the amount of organic compounds released from the refuse.

B. Current research studies and investigations of existing waste disposal sites have provided much information on the degree of attenuation of leachate in a variety of hydrogeologic environments. Empirical predictions of leachate migration from sites is possible using these data, provided that the groundwater regime in the vicinity of a waste disposal site is adequately defined. The predictive model would be improved if existing migration data could be more closely related to the soil properties such as grain size distribution, cation exchange capacity, soil organic content and clay mineralogy.

C. Existing data show that, with intergranular flow, leachate attenuation is significant for fine grained soils. This applies to both solid and liquid wastes. Shortcircuiting of the natural flow pattern could result in significant environmental impact if an adequate attenuation may not have been effected.

D. Leachate controls which can be implemented at waste disposal sites include:

- i) Minimization of infiltration
- ii) Use of in-situ impermeable base soils to direct leachate to a collection and treatment system.
- iii) Groundwater flow manipulation
- iv) Installation of a liner to direct leachate flow to a leachate collection and treatment system. Bentonite has been shown to be the most economic material for landfill liner construction. It is to be noted, however, that care in design must be exercised to ensure that the liner will not deteriorate during the period of leachate production.

E. Collected leachate can be treated by discharging to a PCP treating municipal sewage. Care must be taken to insure that leachate discharge to the pollution control plant does not exceed the total volume of flow to the plant by 10 percent. It has been shown that a ratio of leachate flow to domestic sewage flow exceeding 10 percent may hamper the existing treatment process.

F. Laboratory studies have shown that collected leachate can be treated by on-site conventional and/or chemical treatment processes.

G. Waste disposal sites should be located and designed in a manner that takes advantage of natural processes that can minimize pollution hazard and control leachate migration. The collection of leachate and treatment does not eliminate the discharge of inorganics to the soil but rather concentrates these materials in sludge which is usually deposited on land.

BIBLIOGRAPHY

1. Reinhard, J.J., Ham, R.K., "Final Report on a Milling Project at Madison Wisconsin Between 1966 and 1972, Volume I", U.S. Environmental Protection Agency, 1973.
2. Hughes, G.M., Landon, R.A., Farvolden, R.N., "Summary of Finding On Solid Waste Disposal Sites In Northeastern Illinois", Illinois State Geological Survey, No.45, 1971.
3. Farquhar, G.J., Farvolden, R.N., Hill, H.M., Rovers, F.A., "Sanitary Landfill Studies, Final Report: Volume I", WRI Project 8083 (Waterloo: Waterloo Research Institute, September 1972).
4. Hydrology Consultants Limited, Files.
5. Rovers, F.A., Farquhar, G.J., "Sanitary Landfill Study, Final Report: Volume II, Effects of Season on Landfill Leachate and Gas Production", WRI Project 8083 (Waterloo: Waterloo Research Institute, September 1972).
6. Hughes, G.M., Landon, R.A., Farvolden, R.N., "Hydro-geology of Solid Waste Disposal Sites in Northeastern Illinois, A Final Report on a Solid Waste Demonstration Grant Project, Illinois State Geological Survey, Urbana, Illinois, U.S.Environmental Protection Agency, 1971.
7. Remson, I., Fungaroli, A.A., Lawrence, A.W., "Water Movement in an Unsaturated Sanitary Landfill", Journal of the Sanitary Engineering Division, ASCE, Vol.94, No. SA2, April, 1968, pp. 307-317.
8. "Report on Hagnon Road Landfill Erie Township, Michigan", Unpublished report, Hydrology Consultants Limited, 1974.
9. Brunner, D.R., Keller, D.J., "Sanitary Landfill Design and Operation", U.S. Environmental Protection Agency, 1972.
10. "Landfill Stabilization with Leachate Recycle", Project Director, Pohland, F.G., Project No.EP-00658, Georgia Institute of Technology, School of Civil Engineering, July, 1972.
11. Armentrout, Jr., W.F., Bortner, L.L., "Preliminary Investigation on Landfill Stabilization with Leachate Recycle", Special Research Problem, Georgia Institute of Technology, School of Civil Engineering, September, 1971.

Contd...

Bibliography Contd.

12. Rovers, F.A., Farquhar, G.J., "Evaluating Contaminant Attenuation in the Soil to Improve Landfill Selection and Design", presented at the International Conference on Land for Waste Management, Ottawa, October 1-3, 1973.
13. Fungaroli, A.A., "Pollution of Subsurface Water by Sanitary Landfills, Vol. I", U.S. Environmental Protection Agency, 1971.
14. Ministry of Housing and Local Government, "Pollution of Water by Tipped Refuse", Report of the Technical Committee on the Experimental Disposal of House Refuse in Wet and Dry Pits", H.M. Stationary Office, 1961.
15. Boyle, W.C., Ham, R.K., "Treatability of Leachate from Sanitary Landfills", Journal WPCF, 46, 6 June, 1974.
16. Foree, E.G., Reid, V.M., "Anaerobic Biological Stabilization of Sanitary Landfill Leachate", Report UKY-TR65-73-CE17, University of Kentucky, January 1973.
17. Spencer, G.S., "Chemical and Biological Treatment of Leachate from Sanitary Landfills", M.A.Sc., Thesis, Civil Engineering, University of Waterloo, June 1974.
18. "Township of Hope, Proposed C.P.Rail Haul and Deposit of Toronto Waste", Letter to Mr.K.Wilk, P.Eng., March 1974.
19. "Proposed Resource Recovery and Land Reclamation Project, Crawford Allied Industries Limited, Town of Vaughan", Hydrology Consultants Limited, June 1974.
20. "Final Development Plan and Operational Procedure For York Sanitation Sanitary Landfill Site #4", Hydrology Consultants Limited, June 1974.
21. Symposia, Cincinnati, U.S.A., May, 1974.
22. "Preventing Landfill Leachate Contamination of Water", Office of Solid Waste Management, Research Grants Section, Cincinnati, Ohio, (1972).
23. Mannian, J.J., "Soil Sealing Chemicals and Techniques", Diamond Shamrock Corporation, Painesville, Ohio, 1968.

Contd...

Bibliography Contd.

24. Boyle, W.C., Ham, R.K., "Treatability of Leachate from Sanitary Landfills", Paper presented at the 27th Annual Purdue Industrial Waste Conference, Lafayette, Indiana, May, 1973.
25. Pohland, F.G., Maye, P.R., III, "Landfill Stabilization with Leachate Recycle", Paper presented at the 3rd. Annual Environmental Engineering and Science Conference, Louisville, Kentucky, March, 1973.



W. S. COTTON

CHAIRMAN - SESSION 4
MR. W. S. COTTON
PRINCIPAL CHEMICAL ENGINEER
DUPONT OF CANADA LIMITED
KINGSTON, ONTARIO

"Sulphur Dioxide Removal Systems
Related to Ontario Hydro"

BY

D. HARRISON
Managing Engineer
Pollution Abatement Programs
Ontario Hydro, Toronto, Ont.



D. HARRISON

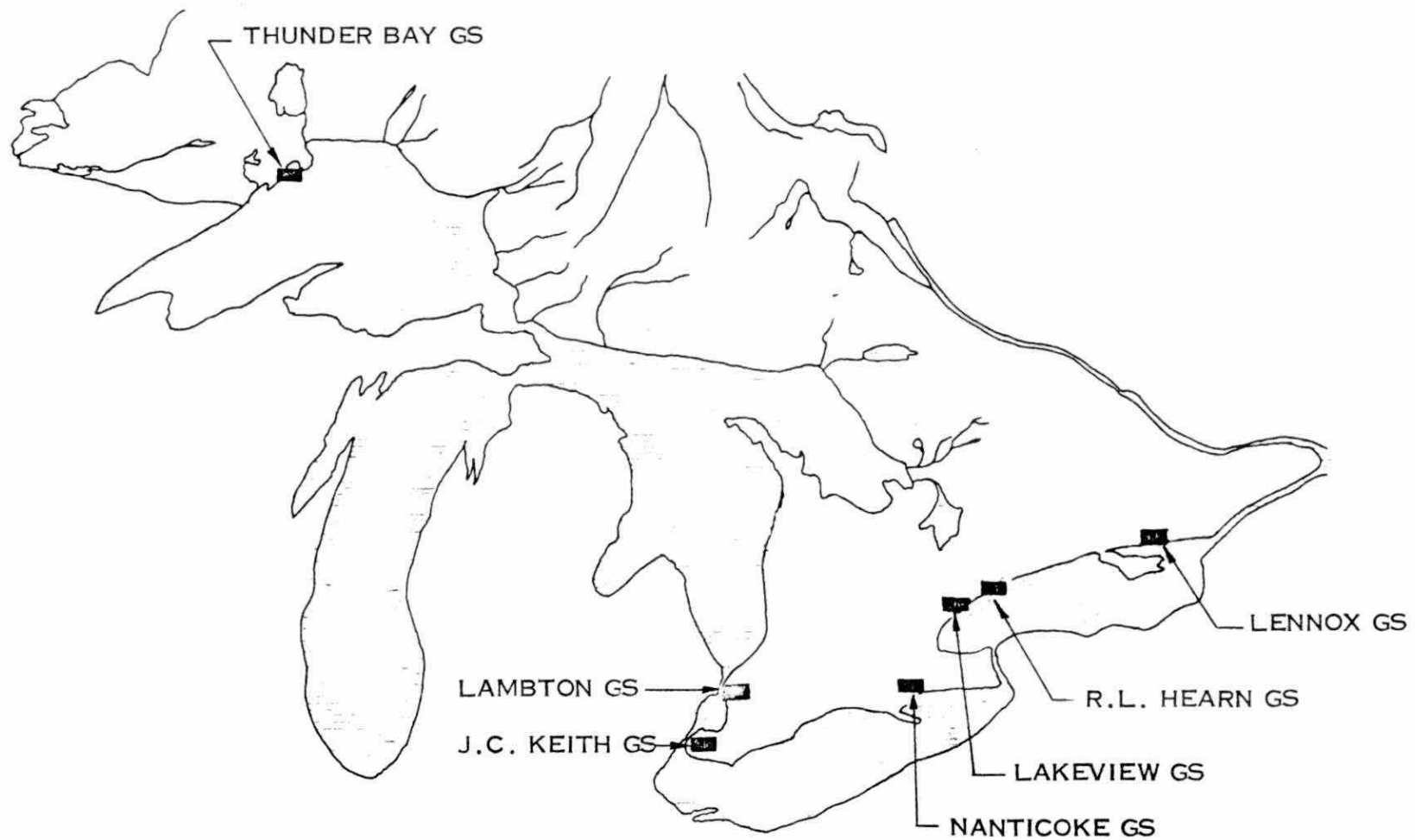
In the late 1950's, the major hydraulic sites for power generation in Ontario had been developed and, to meet future demands for electrical energy, Ontario Hydro turned its attention to the construction and operation of thermal generating stations. Since that time the thermal generating capacity has grown rapidly and there are now six fossil-fuel-fired generating stations operational with a combined total capacity of about 8000 MW (see map).

All of the fossil stations in operation burn coal except for the R.L. Hearn generating station in Toronto which burns both natural gas and coal. The total amount of coal burned for power generation in 1973 was about 7,300,000 tons. The average sulphur content of the coal was 2.15 per cent and most of the sulphur is emitted from the chimneys in the form of sulphur dioxide.

Three methods are used to control sulphur dioxide concentrations in the atmosphere due to emissions from the generating stations:

- a) the use of low sulphur fuels.
- b) curtailment of production or load switching when atmospheric dispersion conditions are poor in one area.
- c) the use of tall chimneys for good dispersion.

Although low sulphur fuels are in short supply and are expensive in the highly developed eastern regions of North America, some natural gas and low sulphur coal are used for electric power generation. The natural gas burned at the R.L. Hearn generating station in Toronto helps to control sulphur dioxide emissions from the station



ONTARIO HYDRO THERMAL GENERATING STATIONS

and, at the Lambton station on the St. Clair River, low sulphur coal is burned when meteorological forecasts indicate poor dispersion conditions for the Sarnia area/1/.

At the Lakeview station in Toronto meteorological forecasts together with measurements of vertical temperature gradients and wind directions and velocities are used to assess dispersion conditions. Sulphur dioxide emissions are restricted when the wind is onshore and are further restricted if there is onshore wind with a temperature inversion.

Tall chimneys are used to obtain good diffusion and dispersion of the flue gases in the atmosphere. The 500 to 700 foot chimneys in use are effective in controlling sulphur dioxide concentrations in the atmosphere at ground level.

Other than the use of low sulphur fuels, there is no commercially available, reliable method for reducing emissions of sulphur dioxide to the atmosphere. However, a considerable amount of research work is in progress, on this continent and in Europe and Japan, to develop processes for removing sulphur dioxide from power plant flue gases. There are 40 or more large scale gas desulphurization units installed, mainly in the U.S.A., Japan and Germany. These have had varying degrees of success but none are considered to be fully developed and sufficiently reliable for power plant application. The main difficulties in developing these processes are associated with two aspects of the problem. First, very small amounts of sulphur dioxide, usually from 0.1 to 0.3 per cent, must be removed from very large volumes of flue gas. A moderately sized (500 MW) coal-fired boiler, at full load, produces approximately 1.4 million cubic feet a minute of flue gas. The second difficulty is with reliability. There is controversy among different groups about reliability and for most installations reliability records are not available.

In this paper some of the processes under development are described, together with research and development work on control processes carried out by Ontario Hydro. A brief discussion of the economic aspects of flue gas desulphurization is also included.

SULPHUR DIOXIDE REMOVAL PROCESSES BEING DEVELOPED

The sulphur dioxide processes being developed may be divided into wet and dry processes. Wet processes are those in which an aqueous medium, either a solution or slurry, is used to absorb sulphur dioxide from flue gas. In electric power plants the gas, which usually contains from 0.1 to 0.3 per cent of sulphur dioxide, is ducted to the stack at a temperature of about 135 C.

Scrubbing this gas with an aqueous medium to absorb the sulphur dioxide, reduces the temperature to about 52C, saturates it with water vapour, and entrains small droplets of the aqueous medium in the gas stream. Most of the entrained liquid droplets are removed by a demister and the remainder are evaporated by reheating the gas. Evaporation of the droplets protects downstream equipment such as ducts, induced draft fan and chimney liner from corrosion.

When the gas is not reheated, it is much cooler than it would be if it had not been scrubbed. The reduced buoyancy reduces the height to which the plume rises after it leaves the chimney and it has been estimated for one case that removal of 60 per cent of the sulphur dioxide by wet scrubbing will make no significant difference in the theoretical ground level concentrations of sulphur dioxide/14/.

Dry processes are those that do not use a liquid medium for scrubbing; therefore, there is no significant cooling of the gas, no reheat is necessary and no significant loss of plume buoyancy occurs.

A brief description of some of the more important processes follows.

Limestone Slurry Process

Detailed descriptions of this process have been published/4,5/. Briefly, it consists of scrubbing the flue gas with an aqueous slurry consisting of a mixture of calcium sulphate, sulphite and carbonate. Absorption of the sulphur dioxide from the gas stream may be accomplished in any one of a number of gas-liquid contacting devices such as a spray tower, a venturi scrubber, a flooded tray or a packed tower. After removal of the sulphur dioxide entrained droplets of slurry are removed in a demister and the gas is reheated before going to the stack. The slurry leaving the absorber is acidic and is supersaturated with respect to calcium sulphate. It goes to a delay tank where the free acid is neutralized and the salts crystallize out of solution before the slurry is recycled to the absorber. Pulverized limestone is added as required and a stream of waste slurry is taken to a thickener and vacuum filter or centrifuge where the solids are separated for disposal and the liquid is recycled.

This process is attractive because there is an abundance of low cost limestone available; calcium is the only alkaline material cheap enough to be used on a non-regenerative basis and the reaction products are only slightly soluble in water and are non-toxic. The disadvantages of the process are that limestone and its reaction products are sparingly soluble in water; therefore,

a slurry must be used and it tends to form mud-like deposits in the system. Furthermore, the calcium sulphate produced forms supersaturated solutions and may crystallize as a hard scale on the equipment. The mud-like deposits can be prevented by adequate irrigation of all internal surfaces with slurry and scale can be prevented by proper control of the chemistry, adequate delay time for crystallization of reaction products and pH recovery, and an abundance of fine particles in the slurry to act as nucleation centres to promote crystallization and eliminate supersaturation.

Table I is a list of large scale limestone slurry process installations at power stations in the U.S.A. Difficulties reported for these systems include equipment failures due to unanticipated problems, corrosion and abrasion. Problems due to scale and deposit formation are still being reported.

TABLE I

Limestone Slurry Process Installations

Electric Power Plants - USA

<u>Utility and Station</u>	<u>Capacity in Megawatts</u>	<u>In Service Date</u>
1. Arizona Public Service Cholla Station	115	Dec. 73
2. Arizona Public Service Four Corners Station	175	Jan. 74
3. Commonwealth Edison Will County Station	165	Feb. 72
4. Detroit Edison St. Clair Station	180	Dec. 74
5. Kansas City Power & Light Hawthorne Station	200	Oct. 73
6. Kansas City Power & Light La Cygne Station	820	June 73
7. Southern California Edison Mohave Station	275	Dec. 73

Lime Process

The equipment used in the lime process is similar to that for limestone. The grinding equipment used in the limestone process is not needed for a lime system but slurring the lime, especially quick lime, may present problems due to the heat evolved and the caking tendency.

Lime is more expensive but also more soluble and more reactive than limestone therefore with lime, the delay tanks may be smaller and there is better utilization of the alkali. The reaction products are the same as for limestone.

Table II lists large scale lime slurry process installations in the U.S.A. and Japan. Reports indicate that the lime process has better reliability than the limestone process.

TABLE II

Lime Slurry Process Installations

<u>Utility and Station</u>	<u>Capacity in Megawatts</u>	<u>In Service Date</u>
1. Louisville Gas & Electric Paddy's Run Station	70	April 73
2. Mitsui Aluminum Co. Miiki Station	156	March 72
3. Duquesne Light Phillips Station	100	April 74

Magnesium Oxide Process

There are descriptions of the magnesium oxide process in papers by Shah/6/ and McGlamery, et al/7/. It is a recovery process in which an aqueous slurry of magnesium oxide and magnesium sulphite is contacted with the flue gas in a venturi-type scrubber. The magnesium sulphite produced is separated from the aqueous phase, dried and decomposed in a rotary kiln to regenerate magnesium oxide for recycling. The sulphur dioxide released in the kiln can be used to produce sulphuric acid.

Magnesium is very reactive, so good sulphur dioxide removal efficiency can be achieved in venturi-type scrubbers. Difficulty has been reported in obtaining suitable crystals of magnesium sulphite for easy separation, and losses of magnesium have occurred.

Table III lists three large scale installations of this process.

TABLE III

Magnesium Oxide Process Installations

<u>Utility and Station</u>	<u>Capacity in Megawatts</u>	<u>In Service Date</u>
1. Potomac Electric Co. Dickerson Station	100	Sept. 73

TABLE III

Magnesium Oxide Process Installations

<u>Utility and Station</u>	<u>Capacity in Megawatts</u>	<u>In Service Date</u>
2. Philadelphia Electric Co. Eddy Stone Station		Jan. 74
3. Boston Edison Mystic Station	150	June 73

Sodium Process

In the sodium process, the sulphur dioxide is absorbed in a solution of sodium sulphite to produce the bisulphite. In the regeneration step, the bisulphite is concentrated and decomposed by heat to strip off the sulphur dioxide and produce sodium sulphite for recycling/8,9/.

Disadvantages reported for this process are the high heat requirement for regeneration and salt losses due to oxidation and side reactions.

Table IV lists large scale installations of the sodium process. The installation at Nevada Power Company's Reid Gardner Station is a non-regenerative system made possible by the availability of sodium carbonate from a nearby natural deposit.

TABLE IV

Sodium Process Installations

<u>Utility and Station</u>	<u>Capacity</u>	<u>In Service Date</u>
1. NIPSCO Mitchell Station	115 MW	Sept. 73
2. Olin Corporation Sulphuric Acid Plant	45,000 SCFM	July 69
3. Japan Synthetic Rubber Co. Ciba Plant	75 MW	June 71
4. Toa Nenryo Kogyo Ltd. Kowasaki Claus Plant	41,000 SCFM	1972
5. Standard Oil of California Claus Plant	--	1973
6. Nevada Power Co. Reid Gardner (Sodium Carbonate non-regenerative system)	160 MW	1973

The wet processes described above are the main ones being considered for or tried in, electric power plant applications. There are many other wet processes in various stages of development.

Three dry processes are also being applied to control sulphur dioxide emissions from power plants.

Catalytic Oxidation

Fly ash is removed from the flue gas in a high-efficiency electro-static precipitator and the gas is then passed through a bed of vanadium pentoxide catalyst at 480 C to convert the sulphur dioxide to the trioxide, which is condensed out as sulphuric acid/10,11/.

This process has the advantage of a simple direct conversion of the sulphur dioxide to sulphuric acid with a minimum number of process steps. The removal of fly ash from the flue gas prior to oxidation is essential to avoid excessive deposition of ash on the catalyst. Even with high-efficiency electrostatic precipitators, some fly ash collects on the catalyst bed and has to be removed periodically. Because the gas phase oxidation must be carried out at 480 C, there could be a heat loss penalty associated with the use of this process.

This process has been demonstrated on a 12 megawatt pilot plant at the Portland Station of the Metropolitan Edison Company/15/. A 110 megawatt unit is installed at the Wood River Station of the Illinois Power Company. In this installation the flue gas is cooled through the usual heat exchangers and is then reheated for the oxidation reaction. After an initial trial the process was shut down for modification of the flue gas heating system.

Activated Carbon Process

In the activated carbon process/12,13/, the flue gas is passed through a bed of activated carbon, the sulphur dioxide is adsorbed and the desulphurized gas goes to the chimney. On adsorption, the sulphur dioxide is converted to the trioxide. When the bed is exhausted it is regenerated in one of two ways:

- (i) a hot gas is passed through the bed to reduce the sulphur trioxide to the dioxide which is released, or,
- (ii) the bed is washed with water to obtain a dilute sulphuric acid solution.

Tests at Ontario Hydro laboratories have shown that activated carbons have low capacities for sulphur dioxide and low gas velocities are essential to obtain good sulphur dioxide removal efficiencies. For these reasons, very large activated carbon beds would be needed

for power plant applications. There are problems with ignition and attrition of the activated carbon and the dilute sulphuric acid produced by water washing is difficult to store and might be difficult to market.

Table V lists large scale installations of the activated carbon process.

TABLE V

Activated Carbon Process Installations

<u>Utility and Station</u>	<u>Capacity in Megawatts</u>	<u>In Service Date</u>
1. Kansai Electric Co. Osaka Station	60	Feb. 72
2. Tokyo Electric Co. Goi Station	50	1971
3. Tokyo Electric Co. Kashima Station	150	--

ONTARIO HYDRO RESEARCH & DEVELOPMENT WORK ON FLUE GAS
DESULPHURIZATION

Limestone Slurry Process

In 1969, Ontario Hydro began its work in this field with a comprehensive review of all the flue gas desulphurization processes which had been reported in the technical literature. On the basis of this review it was decided to develop the limestone slurry process using a spray tower for absorption. There were several reasons for selecting this particular combination of limestone slurry and spray tower.

- (a) In 1969 sulphur prices were low and there were large surpluses of sulphur. Furthermore, at that time with more and more production of sulphur expected as a byproduct from natural gas, there was little incentive to develop processes that would produce sulphur or sulphuric acid. Since 1969 sulphur prices have increased but there are still very large stockpiles of sulphur in Western Canada and the metal extraction industries have developed processes and can produce very large quantities of byproduct sulphuric acid.
- (b) A non-regenerative system was considered preferable to regenerative system. Lime and limestone are the only material cheap enough to be used on a non-regenerative basis and limestone was selected as being the more economic.

- (c) The technical literature showed that scaling could be a problem with the limestone slurry process so the spray tower was selected as the absorber with the most open configuration and least propensity for scale or deposit accumulation. The spray tower has since been adopted for development by a number of other companies.
- (d) The spray tower has two additional advantages which are significant:
 - (i) it has very low pressure drop and this is important when very large volumes of gas are to be processed as in the case of power plants.
 - (ii) it has infinite turn-down ratio which means you can operate the boiler at any load, full or partial, without significantly affecting the performance of the scrubber. This feature is of particular importance to Ontario Hydro where fossil plants will be increasingly used in a cyclic manner to supply peak loads.
- (e) Because Ontario Hydro has a policy of installing high-efficiency electrostatic precipitators on all large thermal stations, it was not considered necessary or desirable to develop a process for removing both fly ash and sulphur dioxide as some commercial companies have done.

One disadvantage of the spray tower is that large liquid to gas ratios are needed for good mass transfer. This has not proven to be a serious problem and 85 per cent sulphur dioxide removal efficiency has been achieved.

After laboratory tests had been successfully completed, a 200 cfm pilot plant was installed at the R.L. Hearn generating station in 1969 and it was used for preliminary trials and equipment selection. The following year a 4000 cfm pilot plant was installed at the Lakeview generating station and this plant is still in operation. The mass transfer characteristics have been determined and data is available for scale-up. There are two problems on which work is continuing:

- (i) Demisting the gas stream: In the spray tower fine droplets of slurry are entrained in the gas stream and must be removed before the gas is released. Ordinary demisters are designed for, and work well on, clear liquid separation.

Slurries tend to form a mud-like deposit on the demister and this gradually builds up and blocks the

the flow of gas. To eliminate this problem, a washing system is installed to keep the demister clean. This is easily achieved in the pilot plant but it is questionable if effective washing can be achieved on scale-up from a 32 inch to a 10 foot demister. Extensive demister washing tests have been completed on full-scale demister blades and a system has been designed and the experimental equipment is now being rebuilt for a final series of tests.

- (ii) The other problem still being worked on is sludge dewatering and disposal. Very large quantities of sludge are produced and to obtain a material with optimum compaction properties for landfill, the sludge has to be dried to 75 per cent solids. It is very difficult to remove water from this sludge. Allowing it to settle in a tank produces a material having 40 to 45 per cent solids. By the use of common methods for separating water from solids, a thickener followed by a vacuum filter or centrifuge, a material having approximately 65 per cent solids is obtained. To achieve the optimum of 75 per cent solids, an extensive series of tests is now underway to evaluate various alternatives such as mixing the 65 per cent solids material with fly ash, and/or adding small portions of lime or Portland cement.

The preliminary results have shown that it is not only possible to produce a material having the optimum moisture content for compaction in a landfill site, but varying degrees of set or hardening can be achieved simply by appropriate adjustment of the mix. The immediate goal in this program is to find the most economic mix for producing material suitable for landfill, and to determine its permeability and leaching characteristics. A secondary goal is to produce a material for road base and similar applications.

The drying characteristics of the sludge are also being determined and the feasibility of drying is being assessed.

The laboratory work completed shows that the sludge can be treated to make it suitable for landfill. The work in progress will determine the most appropriate and economic way of transforming the sludge into suitable landfill material.

The final step necessary is to construct and operate a large plant that can produce sufficient quantities of sludge for large-scale landfill trials. This is needed to confirm the results of laboratory work, to determine possible effects on ground waters, to assess the corrosive characteristics of the fill and to solve any unforeseen problems that may occur.

Preliminary engineering design has been completed for a 100 megawatt installation, and consideration is being given to further work on this project.

Regenerative Processes

Longer term research is underway to assess the possibilities for recycling the sludge produced by the limestone slurry process. Preliminary laboratory work indicates that recycling is feasible but there is much work yet to be done before a final assessment of this process can be given. If a sludge recycling process is developed, the limestone process would then offer the two alternatives of either disposing of or recycling the sludge. Exploratory work has been done on other regenerative processes and considerable work is being done on the ammonia process in co-operation with the Tennessee Valley Authority.

In addition to an extensive in-house research and development program, Ontario Hydro together with a number of U.S. utilities has supported research work on two regenerative sulphur dioxide removal systems, the potassium process and the copper oxide process, neither of which have yet been tried on a large scale on this continent.

ECONOMIC ASPECTS

It is impossible to give an exact cost estimate for the installation of a flue gas desulphurization system. Figures that are published and those obtained privately are usually in the \$30 to \$80 per kilowatt range. However, some cost figures do not include sludge disposal, others include the cost for ponding a wet sludge. Some companies prefer to defer work on the sludge disposal problem for later consideration.

Since many of the installations made are retrofits to existing boilers, real estate costs are seldom considered and there are large variations in the cost of foundations and modifications to existing structures and ductwork. Some cost estimates include new induced draft fans, others simply put in additional fans or upgrade existing fans. Some estimates include reheat of the flue gas, others avoid reheat and run a wet stack. In some cases the purchaser takes care of the civil engineering and foundations, in other cases it is part of the contract. So, costs can only be given for a specific job and then what is included in the cost should be carefully considered.

The Tennessee Valley Authority have done a careful cost estimate for the installation of a 550 MW limestone slurry scrubber on their Widow's Creek plant. The estimated cost for this plant is \$80 per kilowatt.

To put this in perspective, recent costs for building fossil-fuel-fired generating stations are about \$200 per kilowatt. So we can guess that the addition of scrubbers to control mass emissions of sulphur dioxide will probably add approximately 40 per cent to the cost. This is a very high cost to pay for reducing mass emissions of sulphur dioxide when it is very difficult to get any clear evidence that the use of tall stacks together with emission controls based on assessment of dispersion conditions will not prove adequate.

SUMMARY

Extensive research and development work together with the installation and operation of large scale plants has brought about rapid technological advance in flue gas desulphurization systems for application to large electric power plants. Further development work is needed before these systems can be considered sufficiently reliable for routine use. Although cost estimates vary, the addition of sulphur dioxide control systems to power plants could increase capital costs by as much as 40 per cent.

REFERENCES

1. McAdie, H.G. and Gillies, D.K.A. "The Operational Forecasting of Undesirable Pollution Levels Based on a Combined Pollution Index." Journal of Air Pollution Control Association, 23, 941 (1973).
2. Slack, A.V. "An Introduction to Stack Gas Cleaning Technology." Paper presented at Electrical World Technical Conference on Sulphur in Utility Fuels: The Growing Dilemma, Chicago, Illinois. October 25 to 26, 1972.
3. Rochelle, G.T. "A Critical Evaluation of Processes for the Removal of SO₂ from Power Plant Stack Gas." Paper presented at the 66th Annual Meeting of the Air Pollution Control Association, Chicago, Illinois. June 24 to 28, 1973.
4. Saleem, A., Harrison, D. and Sekhar, N. "Sulphur Dioxide Removal by Limestone Slurry in a Spray Tower." Paper presented at the Second International Lime/Limestone Wet Scrubbing Symposium, New Orleans, U.S.A. November 8 to 12, 1971.
5. Elder, H.W. and Thompson, W.H. Transactions of the ASME - Journal of Engineering for Power, 150 to 154, July 1973.
6. Shah, I.S. and Quigley, C.P. "Magnesium Base SO₂ Recovery Process - A Prototype Installation at Boston Edison Company and Essex Chemical Company." Paper presented at AIChE 70th National Meeting, Atlantic City, New Jersey. August to September 1971.
7. McGlamery, G.G., et al. "Conceptual Design and Cost Study - Sulphur Dioxide Removal From Power Plant Stack Gas, Magnesia Scrubbing - Regeneration: Production of Concentrated Sulphuric Acid." Environmental Protection Technical Series. EPA-R2-73-244. May 1973.
8. Potter, B.H. and Craig, T.L. "Commercial Experience with an SO₂ Recovery Process - Wellman-Lord Process." Chemical Engineering Progress, 68, No. 8, 53 to 55, 1972.
9. Sulphur, "Wellman-Lord Process - Secure Future for Alkali Scrubbing?" No. 104, 43 to 46, January/February 1973.

10. Schultz, et al. "The Cat. Ox Process at Illinois Power." Paper presented at 34th Annual Meeting of the American Power Conference. April 1972.
11. Horlacher, W.R. et al. "Four SO₂ Removal Systems." Chemical Engineering Progress, 68, No. 8, 43 to 52, 1972.
12. Brown, G.N. et al. "SO₂ Recovery via Activated Carbon." Chemical Engineering Progress, 68, No. 8, 55 to 56, 1972.
13. Lensuka, T. "Desulphurization Methods for Stack Gas by Activated Carbon." Paper presented at the Second International Clean Air Congress, Washington, D.C., U.S.A. December 6 to 11, 1970.
14. Slawson, P.R. et al. "The Behaviour of Moisture Laden Plumes." Industrial Research Institute Project No. 1021, University of Waterloo, Waterloo, Ontario. Private Contract Research Report.
15. Reminez, R. "Catalytic Route is Ready for Flue Gas Cleanup Jobs." Chemical Engineering, 86 to 88. April 21, 1969.

"Inco's SO₂ Emission Control Program -
Past, Present and Future"

BY

K. SEGSWORTH

Supervisor, Air Management
Ontario Division
International Nickel Co., Ltd.,
Sudbury, Ontario



K. SEGSWORTH

BACKGROUND

The International Nickel Company operates thirteen underground mines and one open pit within the Sudbury Basin; a copper, nickel and iron sulphide deposit located some 250 miles north of Toronto (Figure 1 - Map of Sudbury District). Run of mine ores are treated to produce a copper, a nickel and an iron concentrate by froth flotation and magnetic separation. The four concentrators in the area have a daily ore capacity of 77,000 tons. Nickel and copper concentrates are conveyed to the Smelter which has a daily capacity of 7,500 tons of nickel concentrate and 1,500 tons per day of copper concentrate. Iron concentrates received at Copper Cliff are transported to the Iron Ore Recovery Plant for separate treatment or are stockpiled as a possible future source of iron, sulphur and nickel. The subsequent pyrometallurgical processing of these sulphide concentrates results in the production of large volumes of sulphur dioxide bearing gases. This paper will outline the SO₂ emission control program at the Copper Cliff Smelter and at the Iron Ore Recovery Plant.

ABATEMENT TECHNOLOGY

Two basic options are available to smelters to avoid air pollution difficulties:

1. Dispersion of the dilute smelter gases through tall chimneys.
2. Removal and disposal of SO₂ from smelter gases.

The first option represents no new technology with environmental impact being minimized through extensive dilution

of emission. For the second, an enormous number of procedures have been advanced for consideration. Some have advanced to industrial application, others have been rejected or are under development.

At first glance the recovery of SO_2 from waste gases seems like a relatively simple chemical problem. After all, SO_2 and H_2SO_4 have been articles of commerce for many years and H_2SO_4 is fundamental to the Chemical Industry. Treatment of gases to remove specific constituents has been a standard technique in the production of a host of chemical products so it would be anticipated that many procedures should be available.

SO_2 in the gas is either strong enough to be worked on directly or it can be concentrated to that stage by absorption - desorption. Reactions involve either oxidation to acid, reduction to elemental S or the production of a sulphur salt. Some of the basic options available are indicated in the following table:

TABLE 1

<u>Process</u>	<u>Product</u>	<u>Cost/Ton S</u>
Alkaline Scrubbing	Sulphur salts	\$65 - \$125
Citrate	S	\$45 - \$100
Liquefaction	Liquid SO_2	\$40
Catalytic Oxidation	H_2SO_4	\$25 - \$ 30

Costs are based on 1970 figures and include, where applicable, absorption - desorption costs to bring low strength smelter gases up to necessary strength for the various fixation alternatives.

Alkaline Scrubbing

Absorption of SO_2 in an alkaline solution to produce a sulphite/sulphate salt is illustrated by the use of either lime or ammonia solutions to produce either calcium sulphate or ammonium sulphate. Calcium sulphate is normally a throw away product with no by-product credit. Ammonium sulphate has limited value as a fertilizer ingredient since it is a relatively dilute nitrogen carrier, not competitive with NH_3 and urea. Thus, in these alkaline scrubbing procedures, the problem of disposal of the final solid can be equally as difficult environmentally as the problem of dispersing large volumes of gas.

The superficial simplicity of the reaction of lime water with SO_2 has led to much emphasis on alkaline scrubbing. Discovery that the reaction is not as simple as stoichiometry indicates has resulted in substantial development work on conditions of reaction and materials of reaction. Much controversy has arisen in the U.S. over

whether the technology is presently adequate for immediate application to power plants.

For a variety of reasons, those installations which use limestone or lime scrubbing have encountered many operating difficulties. These difficulties centre on such features as the properties of calcium sulphite, the slow oxidation of calcium sulphite to sulphate, poor settling characteristics of the waste precipitate and scaling of equipment. The process was pioneered at the Battersea power plant in the U.K. in the 1930's, but eventually was abandoned after identifying these problems. In large measure, current development work is concluding the same thing as the early workers had concluded in the U.K. Quite apart from these process difficulties, another poor feature of the alkaline scrubbing techniques is the fact that the off-gases are cool and saturated with moisture. There is little or no plume rise from a chimney under these circumstances and the foggy gas very often drops quickly to the ground. To overcome this condition requires heating the gas which in turn represents a direct waste of energy.

Wet limestone or lime scrubbing finds its most logical application in very dilute SO_2 streams. With cheap limestone, the cost of removal of S, assuming all operating problems are overcome, is approximately \$65/ton of S. This cost can increase to \$100/ton of S if waste gas reheating is necessary or any of the operating problems are encountered.

Ammonia scrubbing does not present the operating difficulties associated with calcium based scrubbing, but more expensive reagent costs increase S removal cost to about \$125/ton of S based on \$50/ton ammonia.

Magnesium oxide scrubbing with regeneration of MgO and production of sulphuric acid from SO_2 results in a conceptual cost for S removal of about \$70/ton of S.

Citrate Scrubbing

Citrate scrubbing which produces elemental sulphur by reduction of absorbed SO_2 with H_2S gives a unit production cost of about \$80/ton of S if credit is given to the recovered S of \$20/ton. Without such credit, the cost is \$100/ton S.

From this review of absorption based procedures, we see that the cost of sulphur fixation varies between \$60 and \$125 per ton of S fixed. We see also that the procedures produce a product that must be disposed of either to a tailings dump or to an available market.

Sulphuric Acid

With concentrations of SO_2 of about 5 - 10% sulphuric acid can be produced at a cost of about \$25

to \$30 per ton of S fixed. This represents the most favourable economic approach to sulphur fixation. On the negative side, there is not always a market available for disposition of acid, especially large quantities. In this case, surplus production would have to be neutralized with limestone which creates the same disposal problem as in the case of lime scrubbing. It should be appreciated that calcium sulphate has a substantial solubility in water, so that impounded calcium sulphate will eventually wind up in the watercourses so that the pollution problem is largely transferred from air to water.

Sulphur

Production of sulphur from SO_2 uses a reducing agent such as coke or methane to convert a part of the SO_2 to H_2S for subsequent reaction of the H_2S and SO_2 to give elemental sulphur. Without going into detail, it can be said that the cost of such production is about \$45/ton of sulphur on a previously concentrated cleaned to market grade liquid SO_2 at a cost of \$40 per ton of S.

INCO CONTROL PROGRAM

It will be recalled that three separate metal sulphide concentrates are subject to pyrometallurgical treatment at Copper Cliff. This section will discuss the control program applied to each concentrate.

Iron

Pyrrhotite concentrate containing 58% iron and 35% sulphur is subjected to an INCO-developed fluid bed roaster/kiln pyrometallurgical process designed to produce roaster gas containing about 8% SO_2 (Figure 2). All gases are directed to a complex of three sulphuric acid plants where the gas is converted to acid by the contact process. The acid plant facility owned and operated by CIL produces 2,500 tons per day of 100% H_2SO_4 , and represents the largest acid producing facility from a metallurgical source in the world. Work is in hand to increase the capacity of these plants. Acid plant tail gas is emitted through a 635 foot stack. Total SO_2 emission is limited to 250 tons per day.

Copper

Copper sulphide concentrates produced from the Sudbury ores are smelted by the INCO Oxygen Flash Smelting Process developed soon after World War II (Figure 3). The concentrate and a flux material are injected with tonnage oxygen of 95% purity into a furnace where a "flash" combustion of iron sulphide takes place. With use of tonnage oxygen a gas containing 80% SO_2 is produced, cooled, cleaned and delivered to a CIL liquefaction plant. Production of liquid SO_2 is 100,000 tons per year representing the largest

supply of this industrial chemical on the continent.

Nickel

The Copper Cliff Smelter Process Flow Chart is shown on Figure 4. Nickel concentrate containing some copper is roasted in a Fluid Bed Roaster or in Nichols-Herroschoff roasters and the calcine is fed to reverberatory furnaces for melting and matte/slag separation. Furnace matte is blown in Pierce-Smith converters to an iron-free matte then slow-cooled to promote separate grain growth of nickel sulphide, copper sulphide and metallics. The matte is again crushed, ground and flotation separated with the nickel sulphide processed further into nickel oxide and the copper sulphide returned to the converter aisle and blown to blister copper.

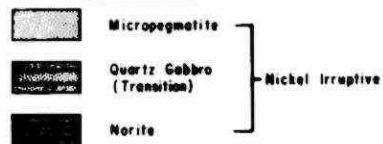
The Smelter Flow Sheet incorporating roasters/reverberatory furnaces/converters, represents the great majority of Smelter Flowsheets operating in the world today. The resulting gases from these relatively "open" smelting facilities contain typically 1% or less SO_2 . At Copper Cliff, the collected gases result in a design volume of 7 million cubic feet per minute of approximately 1% gas at an average temperature of over 400°F . In the late 1960's faced with a still-developing sulphur dioxide technology, and the encouraging results from tall stack installations in the U.S. and England, it was decided to adopt a dispersion approach through the installation of a carefully designed flue collection and gas cleaning system with discharge through a tall stack. In establishing the chimney height required, the Holland formula for plume rise and the Pasquill-Gifford formula for plume dispersion, models used by the Ontario Ministry were fundamental to the exercise. Calculation indicated a chimney height of 1000 feet would satisfy the Provincial air quality standards, however, in recognizing that local meteorological weather conditions could provide adverse dispersion conditions, a 25% safety factor was added and construction of a 1250' stack, the tallest in the world was approved.

At this time our tall stack has been in operation for nearly two years. Total cost of the stack, the connecting flues and the addition and expansion of gas-cleaning facilities was 25 million dollars. Monitoring results of the Sudbury area air have demonstrated the predicted improvement in the air quality.

Beyond dispersion, the company continues in its efforts to decrease SO_2 emission from its smelters. We have had some success in this regard as a result of the removal from the smelter burden of additional pyrrhotite. This has permitted closing the Coniston Smelter and has led to a significant decrease in SO_2 emissions from the Copper Cliff Smelter.

SUDBURY DISTRICT

LEGEND



SYMBOLS



REDUCTION PLANTS

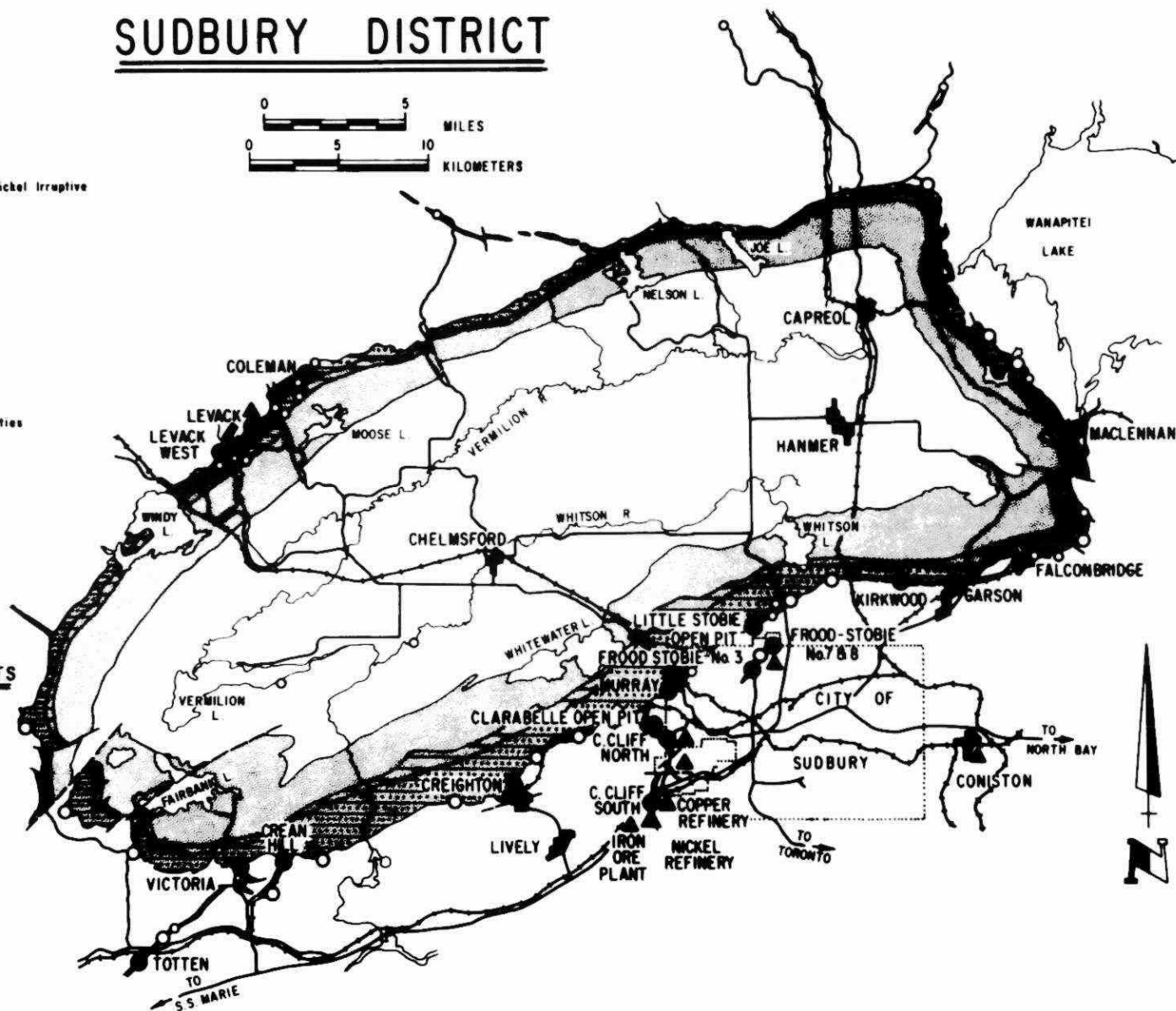
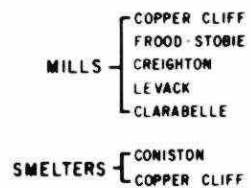


Figure 1

IORP & CIL GAS FLUE SYSTEM

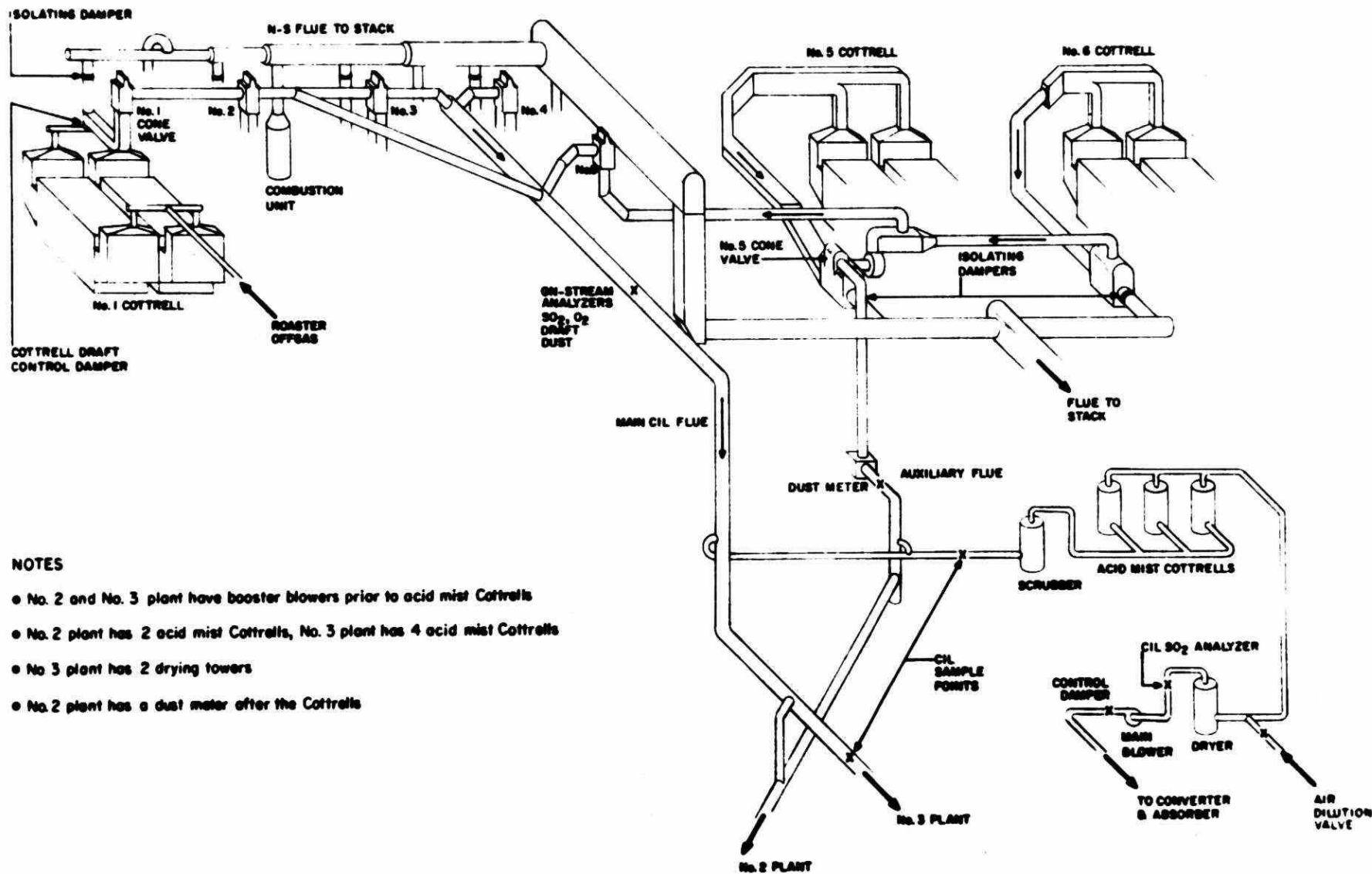
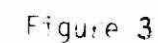


Figure 2

THE INTERNATIONAL NICKEL COMPANY
OF CANADA, LIMITED

Legend

 product tanks

Cutaway view of Inco oxygen flash smelting furnace.

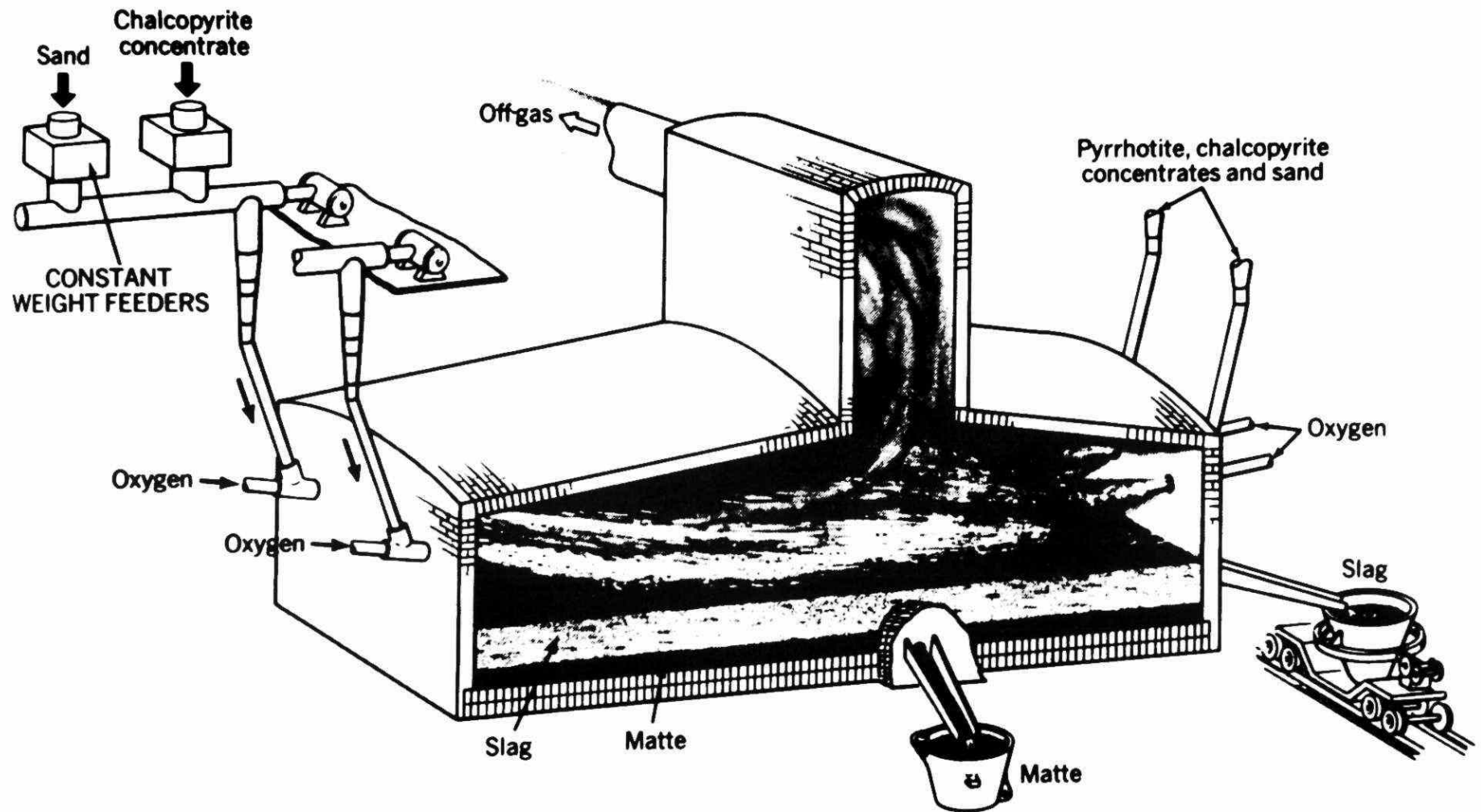


Figure 4



N. CONROY

"Extensive and Intensive Lake Studies in the Sudbury Area"

BY

N. Conroy, Chief, Water Resources

and

L. Maki, Biologist

Ministry of the Environment

Sudbury, Ontario

Introduction

A serious water quality problem exists in certain lakes in the greater Sudbury area where the hydrogen ion and/or heavy metal concentrations are elevated to the point that entire populations of fish have been lost and yet no direct discharge to these lakes has occurred. In recognition of the problem, the Ministry of the Environment has founded several inter-related programmes to quantify the extent and severity of the impairment and to reclaim lakes.

This paper highlights the interim results of two of these programmes - The Intensive and Extensive Monitoring. Both programmes are ongoing and as such these results are necessarily interim. Subsequent papers will describe aspects of the other programme as well as problems related to the direct discharge from the sulphide mineral recovery in industry in Ontario.

Extensive Monitoring

In August 1973, a study was initiated to investigate the feasibility of monitoring more than 100 lakes in the greater Sudbury area by float equipped aircraft with the purpose of; (1) documenting the aerial extent of the acid lake situation and (2) collecting reliable background information on the lake-water chemistry in order to assess major variable changes that might occur in the future. The programme was successful and many of the problems associated with aircraft sampling were solved such that a full-scale programme is now under way. As well, certain findings from that study were worthwhile to report independently (Conroy, Jeffries and Kramer, 1973).

In the 50 lakes studied in August 1973, conductivity ranged widely from 28 to 264 $\mu\text{mho cm}^{-1}$ with a distinct bimodal distribution favouring low conductivity lakes. Surface pH varied by four orders

of magnitude from 4.0 to 8.2 and along with alkalinity and conductivity, had a defined relationship as provided in figure 1. High conductivity lakes were related to high alkalinities, therefore high buffering capacity resulting in low pH values. Furthermore, lakes with very low pH had higher conductivity due primarily to an increase in the hydrogen ion and sulphate ion concentrations in these waters.

As provided in table 1, 20 per cent of the lakes studied had pH values below five indicating an environment definitely unsuitable for fish survival. An additional 10 per cent showed pH's of less than 5.5 - below which reproductive success for sensitive fishes, (salmonids) at least, is questionable.

The sulphate ion concentration in the lakes varied from 0.2 to 32.4 mg l⁻¹ with a mean of 12.5 (s=5.2). The aerial distribution of sulphate showed a distinct tendency toward elevated concentrations in the vicinity of Sudbury, reflecting the atmospheric fall-out to the lakes from the sulphide ore smelting industry located there.

The extent to which the major ions, as provided above, varied from lake to lake within this relatively small region is related to the variability in the lithology. Kramer (1964) states "the ultimate 'source' of all constituents in the fresh water is either the lithosphere (sediment) or atmosphere." To understand the relationship involved, a nomograph depicting the relationship between the concentration of the ions in water (as measured by conductivity or total dissolved solids), the source material - quartz, cations-silicates or carbonates and the state of subdivision of the source material is shown in figure 2 after Conroy (1972). A basin dominated by glacial drift can only yield sufficient ions to the lake water pool to yield conductivities greater than approximately 150 $\mu\text{mho cm}^{-1}$ if calcium carbonate is an important constituent of the basin material. Lakes dominated by quartz or quartzite (a major mineral in the greater Sudbury area) must yield low conductivity and the lakes will be very dilute even if the state of subdivision of the quartzite material is relatively fine. The bimodal distribution of conductivity reflects the effect on one end of the domination by calcareous material (high conductivity) and on the other extreme the lack of domination by calcareous material. In the study area, dilute non-calcareous lakes predominate since lithology in the region is described as "Pre-cambrian bed rock with a thin veneer of unconsolidated sediments". As the influence of the calcareous material disappears, the conductivity, alkalinity and pH are more strongly affected by atmospheric addition of sulphuric acid. At the extreme end, and lakes exist in the greater Sudbury area at this extreme, there is so little buffering capacity available that even very small additions of sulphuric acid are sufficient to cause a significant increase in the hydrogen ion concentration.

Further, since the negatively charged species, hydroxyl and carbonate/bicarbonate, are important metal complexing agents, lakes elevated in these species (high pH lakes) will complex more of the heavy metals. The complexed metals are more easily precipitated into the bottom sediment and are, in the complexed state, less toxic

FIGURE 1

Relationship of pH to Alkalinity and Conductivity

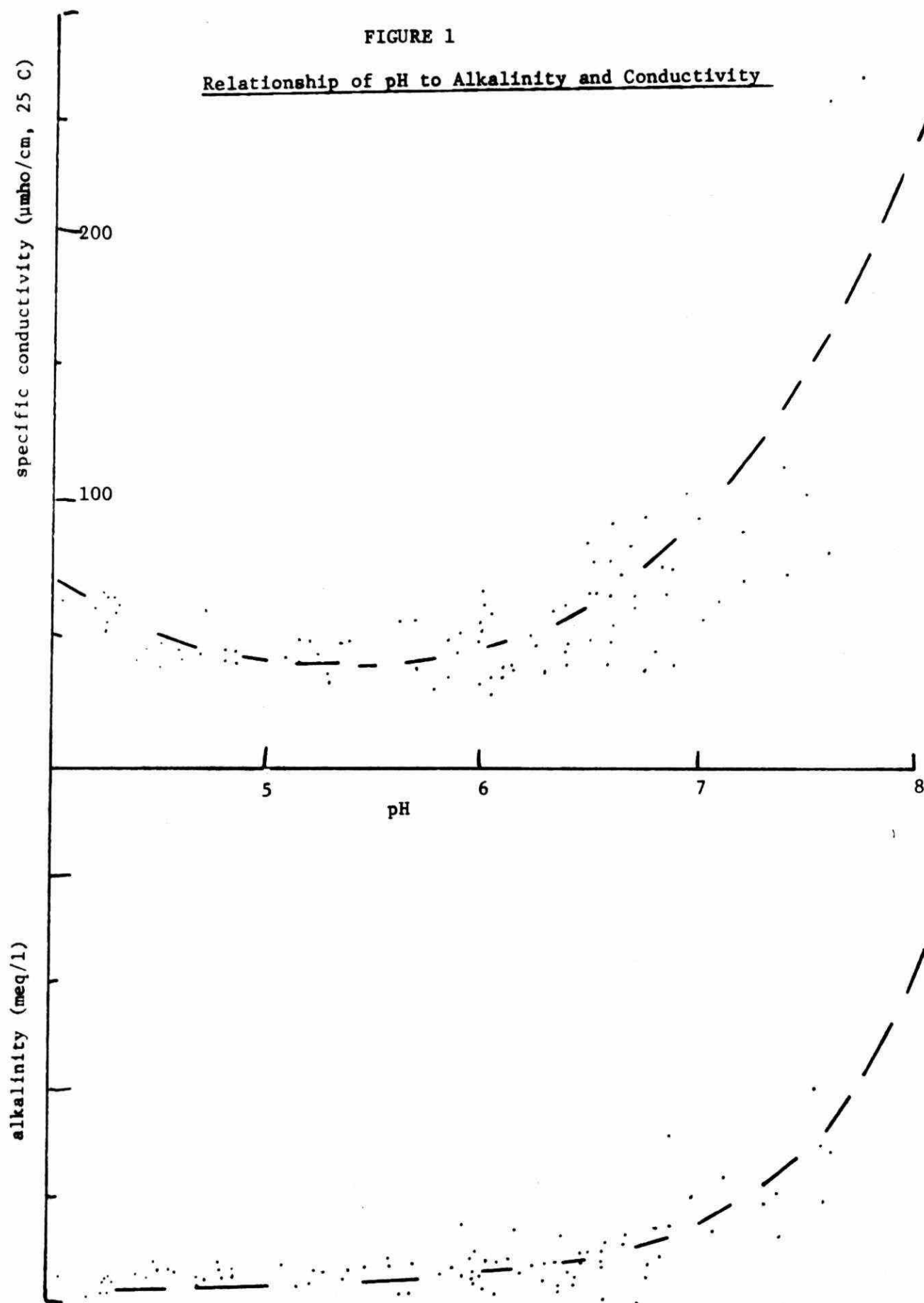


FIGURE 2

Figure 2 Relation between lithological nature of lake basins and total dissolved solids

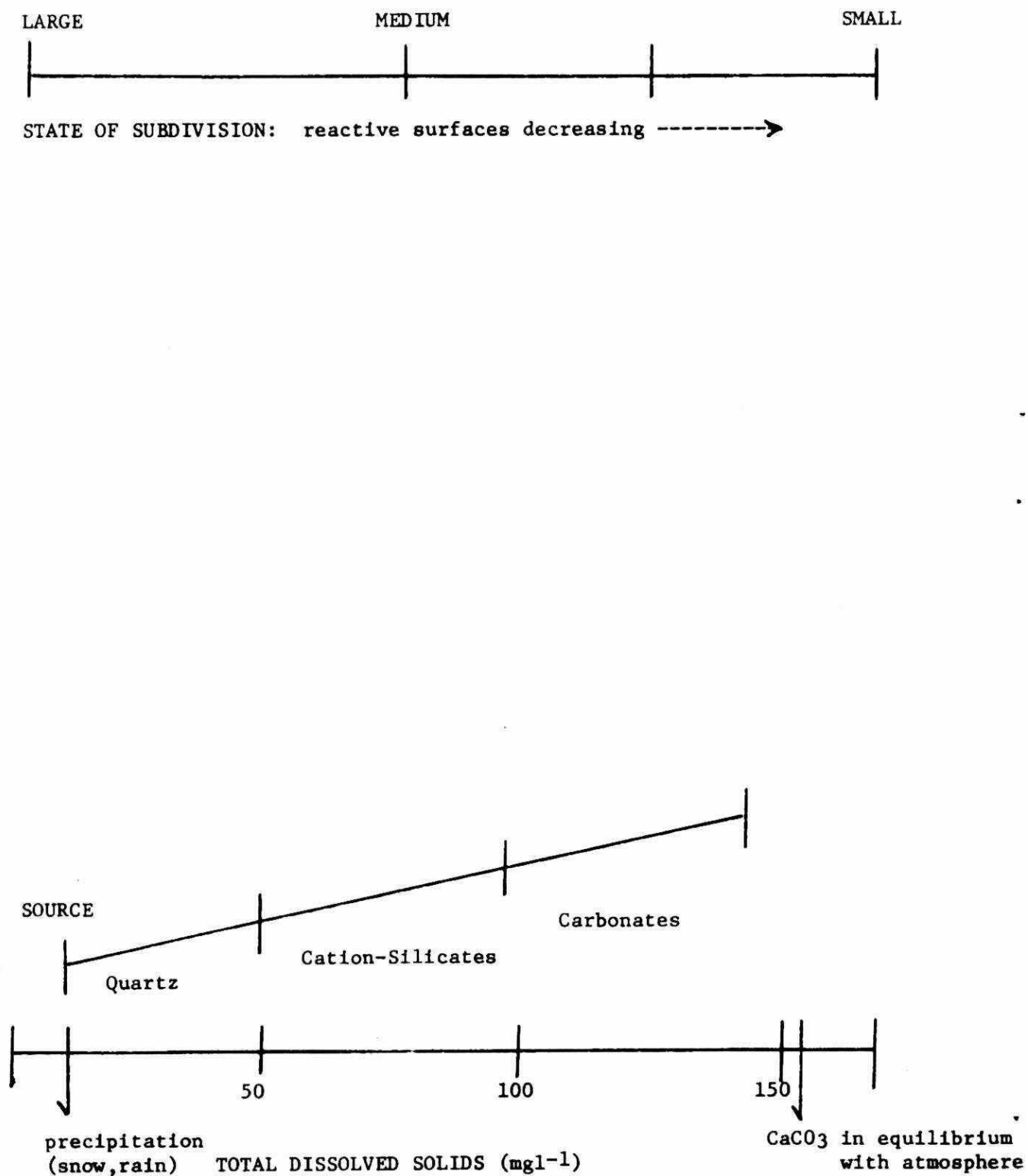


TABLE 1
Summary and Interpretation of pH data
Relative to Fisheries Productivity

RANGE	NO.	CUMMULATIVE PER CENT	COMMENTS
4.00-4.50	6	8.3	unsuitable for fish Beamish and Harvey, 1972
4.51-5.00	4	2.01	"
5.00-5.50	4	28.6	reproductive success ques- tionable Duoderoff and Katz, 1972
5.51-6.00	5	39.0	
6.01-6.50	13	65.0	
6.51-7.00	10	86.0	MOE criteria for protection of fish
7.01-7.50	5	96.0	
7.51-8.00	1	98.0	
8.01-8.51	1	100.0	

to aquatic life. In low pH lakes, with necessarily a deficiency of these ions, species growth may be directly impaired by the low pH as well as by the relatively high concentration of free heavy metal ions.

Intensive Monitoring

The Ministry's Intensive Monitoring Programme of the Sudbury Environmental Study is designed to study the variations in water chemistry between selected lakes and to compare the biological dynamics in acid and non-acid lakes. The working hypothesis for the study is that acidification results from the deposition of atmospherically conveyed acid and acid producing gases in lakes as a result of emissions from the large sulphide ore smelting complexes in and around Sudbury. Further, it is hypothesized that the resulting hydrogen ion concentration in these lakes depends on: a) the load of acid to the lake and b) the inherent buffering capacity of that water. The two major extensive variables then become (1) the distance and direction from the suspected source since lakes in the prevailing wind direction and at a relatively close distance would receive the greatest load, and (2) the geological setting since the ability of the lake water to assimilate hydrogen ions depends on its inherent buffering capacity. This buffering capacity is derived from the chemistry of the basin. As provided, lakes in a geological setting high in calcite provide a much higher hydrogen ion assimilative capacity than lakes in a non-calcareous, and in particular, a quartzite basin.

The two lakes selected to study the distance and direction factor in the first year of the study were Fairbanks Lake (32 km west of Sudbury) and Nelson Lake (26 km north northwest of Sudbury). In most respects, these lakes were similar; that is, both were located in the nickel eruptive zone with approximately the same extent of surfacial cover, both were relatively similar in size and historically supported a viable lake trout fishery. The major difference at this time between the lakes is the elevated hydrogen ion and heavy metal concentration in Nelson Lake as compared to Fairbanks Lake, (see Table 2). The effect of the reduced pH and elevated heavy metal is reflected in the biological dynamics as a reduced bottom fauna diversity and reduced chlorophyll a concentration as provided in table 3.

Precipitation analysis indicate that Nelson Lake lying more in the prevailing wind direction from Sudbury received a greater load of heavy metals including nickel, copper and lead than did Fairbanks Lake. (See Table 4).

The two lakes selected to study the effects of geological study on water quality were Nellie Lake and Bassoon Lake. Both lie approximately 65 km south west of Sudbury.

TABLE 2

A COMPARISON OF THE GEOGRAPHY AND
GEOLOGY OF THE STUDY LAKES AND RANGES
IN CONCENTRATIONS OF SELECTED PARAMETERS

LAKE	DISTANCE FROM SUDBURY Km	DIRECTION	BASIN GEOLOGY	pH	SECCHI DISC m	CONDUCTIVITY umhos / cm	ALKALINITY AS CaCO_3 mg/l	COPPER mg/l	NICKEL mg/l	ZINC mg/l	IRON mg/l	CADMI mg/l
FAIRBANKS	32	West	Nickel Irruptive	6.51 -7.67	7.0- 10.5	61 - 72	6.9 - 16.0	<.003- .036	<.004- .010	<.003 -.020	.003- 0.80	<.001
NELSON	26	North- Northwest	Nickel Irruptive	5.46 -5.96	7.7- 10.25	44 - 47	0.0 - 4.9	<.003- .017	.014- .019	.007 -.043	.015- 0.29	<.001
BASSOON	61	South- west	Proterozoic Limestone Sediments	6.60 -8.26	3.0- -4.25	88 - 99	17.3 -30.1	.003 -.057	<.004 -.014	.003 -.045	.017- .110	<.001
NELLIE	72	South- west	Lorraine Quartzite	4.45 -4.82	17.0- 25.0	44 - 53	0.0 - 3.0	<.003 -.069	.010 -.019	.012 -0.30	.035- 0.20	<.001

TABLE 3

RELATION BETWEEN A CHLOROPHYLL a,
BOTTOM FAUNA DIVERSITY AND pH IN STUDY LAKES

<u>LAKE</u>	<u>pH</u>	<u>CHLOROPHYLL a</u> <u>ug/l</u>	<u>BOTTOM FAUNA DIVERSITY</u>	
			<u>Range</u>	<u>Lake Mean</u>
FAIRBANKS	6.51	0.20	0.00	0.91
	-7.67	-2.40	- 2.06	
NELSON	5.46	0.20	0.00	0.48
	-5.96	-1.40	-0.87	
BASSOON	6.60	0.40	0.00	0.76
	-8.26	-3.60	-2.49	
NELLIE	4.45	0.20	0.00	0.23
	-4.82	-0.50	-0.91	

TABLE 4
RANGES IN HEAVY METAL CONCENTRATIONS
OF PRECIPITATION SAMPLES COLLECTED
ON STUDY LAKES

<u>LAKE</u>	<u>COPPER</u> <u>(ug/l)</u>	<u>NICKEL</u> <u>(ug/l)</u>	<u>IRON</u> <u>(ug/l)</u>	<u>ZINC</u> <u>(ug/l)</u>	<u>CADMIUM</u> <u>(ug/l)</u>
FAIRBANKS	7.50-28.0	0.50-11.5	40.0-277.0	1.50-211.0	<0.10-0.80
NELSON	6.50-149.0	6.0 -18.5	62.0-281.0	32.0 -152.0	<0.10-3.50
BASSOON	6.0 - 43.5	0.0 - 8.0	48.0-238.0	55.0 -181.0	<0.10-1.10
NELLIE	5.5 - 33.5	0.0 - 2.5	99.0-153.0	3.0 -123.0	0.75-1.50

The basin surrounding Nellie Lake is corrairie quartzite of the locally famous LaCloche Mountains. As provided, quartzite is a very resistant rock type and provides virtually no ions to the lake water. The basin surrounding Bassoon Lake is proterzoic limestone of the Espanola Formation. As expected, the water chemistry in these two lakes is markedly different in many respects. Bassoon Lake had an inherently higher buffering capacity, higher conductivity, and an alkaline reaction at pH 7.2. Nellie Lake, on the other extreme, has a very acid reaction at pH 4.5 - alkalinity was virtually absent and conductivity was low.

As expected, biological activity in Nellie Lake was very much reduced as compared to Bassoon Lake. Chlorophyll a was often too low to measure and the bottom fauna community was composed almost entirely of pollution tolerant immature midges, providing near zero diversity. (See Table 2., 3., 4., and Figure 3).

Summary

Lakes exist in the greater Sudbury area with low pH and elevated heavy metal concentrations and our data supports the fact that susceptibility to pH depression and elevated heavy metals is a function of :

1. the distance and direction from the source - the large sulphur dioxide generators at the ore smelting industry and
2. The geological setting of lake basin. Lakes containing calcium carbonate in their drainage basin are more highly buffered and, as such, can neutralize an acid input. Lakes and bed rock zones impoverished in calcium carbonate have less ability to neutralize the acid input to the point that even small loadings of sulphuric acid are sufficient to make the lakes more acid.

The biological dynamics of lakes are reduced as pH declines (See Figures 3 and 4) and heavy metals become more abundant to the point that entire fisheries can be destroyed.

Existing Programmes

The intensive and extensive monitoring aspects of the Sudbury Environmental Study are continuing. A full-scale extensive monitoring programme commenced in June 1974. It is planned that sampling will be carried out on more than 100 lakes at several locations during the ice-free periods in 1974 and 1975 to provide a more accurate picture of the aerial extent of the recognized problem as well as to provide a reliable record of the existing lake water quality conditions.

With respect to the intensive monitoring programme, four new lakes were selected for study in 1974, using the two major extensive

FIGURE 3 COMPOSITION (%) OF BOTTOM FAUNA COMMUNITIES

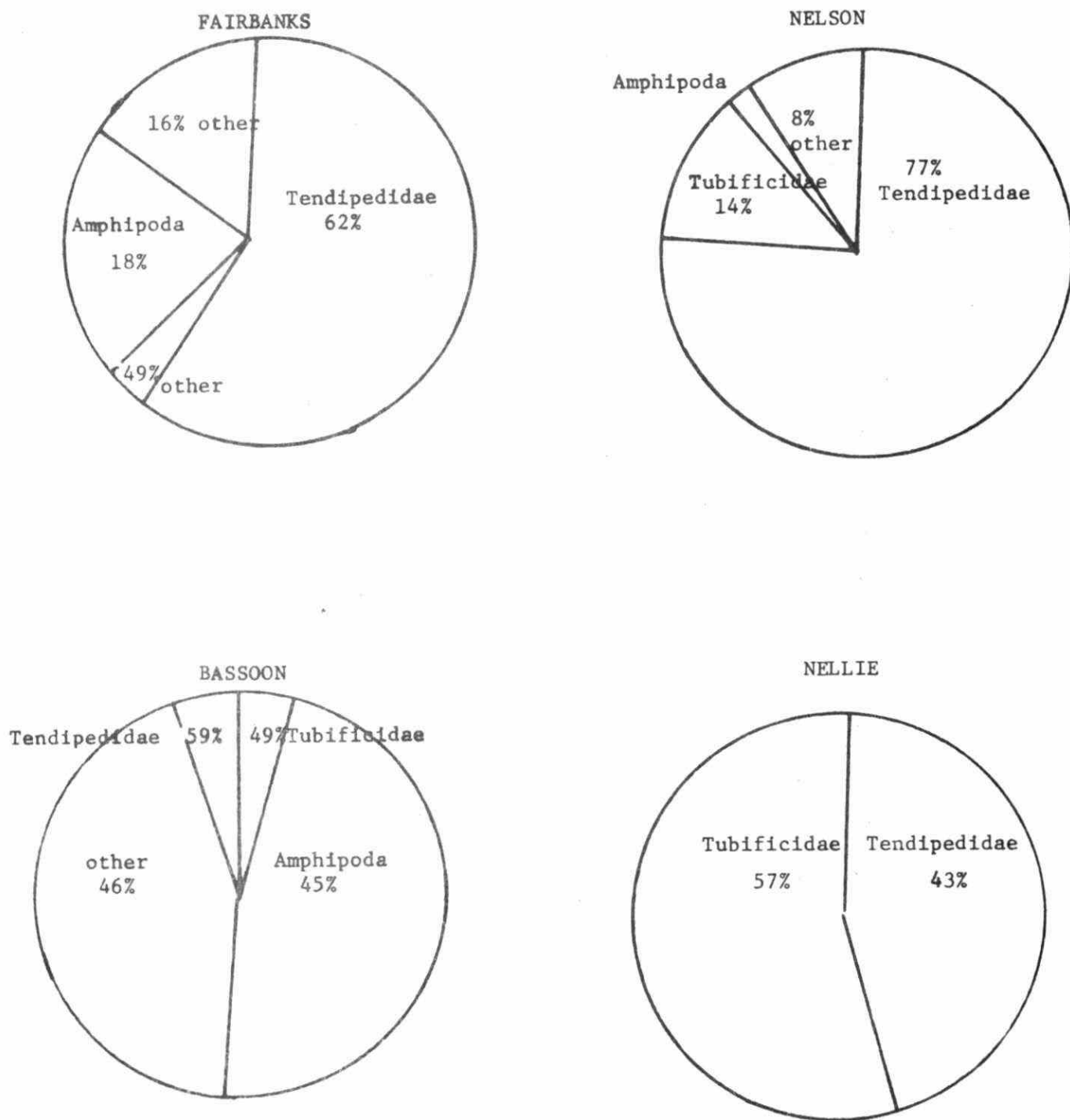


FIGURE 4A INTENSIVE MONITORING - MEAN pH VS MEAN CHLOROPHYLL α

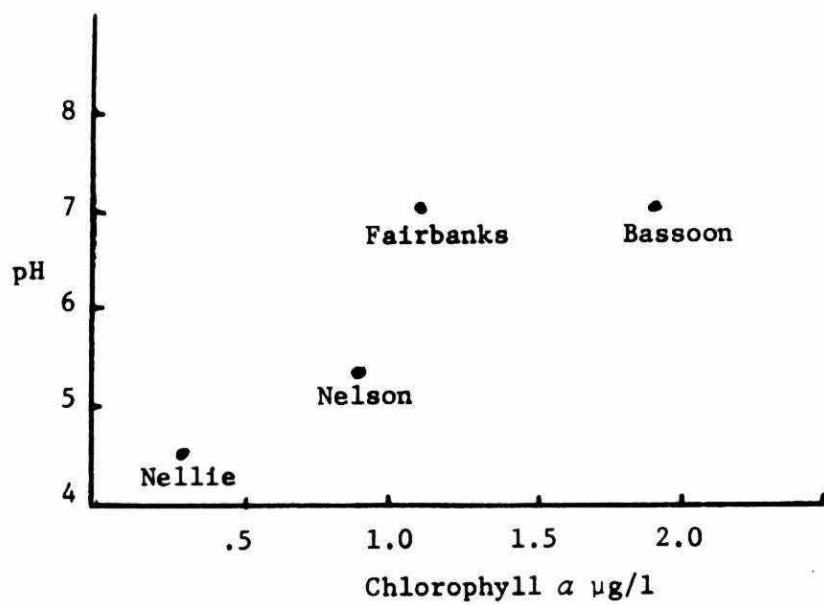
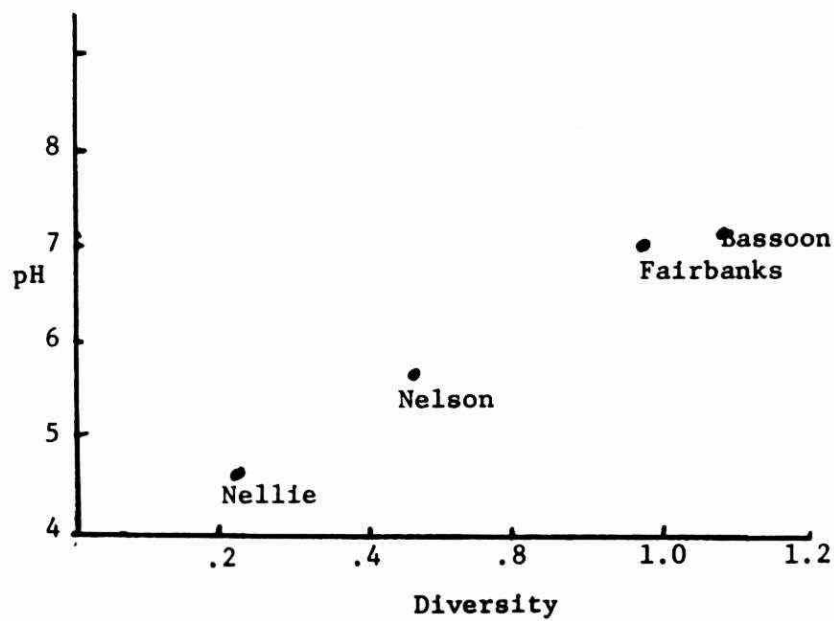


FIGURE 4B INTENSIVE MONITORING - MEAN pH VS MEAN BOTTOM FAUNA DIVERSITY



variables, distance and direction, and geological setting as the comparative basis. It is felt that this approach will provide more data than reassessing the four lakes chosen for the 1973 field season and reported on herein. It is planned that progress reports for the various programmes conducted in 1974/75 will be made available in report form.

REFERENCES CITED

- Beamish, R. J. and Harvey, H. H., 1972. Acidification of the La Cloche Mountain Lakes, Ontario and resultant fish mortalities, *J. Fish. Res. Bd.*, 29.
- Conroy, N. 1972. Classification of Precambrian Shield lakes based on factors controlling biological activity M. Sc. Thesis, McMaster University, Hamilton.
- _____, N., D. Jeffries and J. R. Kramer, 1974, Acid Shield Lakes in the Sudbury Ontario Region. 9th Canadian Symposium on Water Pollution Research, University of Western Ontario.
- Duodoroff, P. and Katz, M., 1950. Critical review of literature on the toxicity of industrial wastes and their components to fish. I. Alkalies, acids, and inorganic gases, *Sewage Ind. Wastes* 22.
- Kramer, J. R. 1964. Theoretical model for the chemical composition of freshwater with application to the Great Lakes. Great Lake Div. University of Michigan. 1:147-160.

"Environmental Aspects of
Acid Mine Wastes"

BY

M. GERMAN

Biologist

Technical Support Section
Regional Operations Division
Ministry of the Environment



M. GERMAN

INTRODUCTION

In general terms, the environmental problems facing the mining industry in the Sudbury area originate from both the extractive and milling operations which waste liquids and the smelting operations which waste gaseous by-products. The purpose of this paper is to provide an overview of the potential environmental problems associated with the mining and milling activities. Unlike my colleagues who will be confining their discussions to the Sudbury situation, I intend to draw on the results of an investigation undertaken in an area somewhat removed from Sudbury. The reason for this approach rests with the difficulty of isolating a body of water in the Sudbury area which receives a liquid waste discharge from a mining operation and is not, at the same time, at least potentially influenced by the input of contaminants from the atmosphere. The study involved intensive sampling during 1970 of a series of lakes forming part of the Black River Watershed in the vicinity of Manitouwadge, Northwestern Ontario. While rather remote from Sudbury, the Manitouwadge findings are believed to be generally applicable

to waters receiving liquid waste discharges from the mining and milling segments of the mining industry and, therefore, provide some insight into the problems facing the mining industry in the Sudbury area.

GENERAL DESCRIPTION OF MINING OPERATIONS

A major base-metal mining camp was established in the Township of Gemmell near Manitouwadge in 1957 when Willroy Mines Limited and the Geco Division of Noranda Mines Limited initiated mining and milling operations. Both developments involve conventional underground mining and surface milling techniques for the recovery and concentration of copper, lead and zinc values from their respective metallic sulphides-chalcopyrite, galena and sphalerite.

During 1970, these operations included the mining and milling of approximately 1300 tons of ore daily at the Willroy operation and a further 5000 tons per day at the Noranda Mine. The only major difference in milling procedure between the two companies during 1970 involved the use of anhydrous ammonia for pH adjustment in the copper and zinc circuits at Noranda Mines Limited. Willroy Mines Limited was utilizing lime as a neutralizing agent.

Following treatment in separate tailings impoundment facilities, the decants of waste water resulting from these operations flow to lakes of the Black River system. Contaminants from the Willroy mining and milling operation are directed to Manitouwadge Lake via Willroy Creek. The decant from Noranda Mines Limited discharges to Mose Lake through a drainage channel referred to in this report as Noranda Creek. Fox Creek which flows to Manitouwadge Lake also carried seepage contaminants originating from the Noranda impoundment facilities.

Domestic wastes from Manitouwadge are collected for conveyance to an adjacent watershed. Thus, with the exception of a small townsite of Willroy Mines Limited which is serviced by septic

tanks, the only domestic wastes which have access to the Manitouwadge Chain of Lakes are those which originate from within the mines and mills.

DESCRIPTION OF STUDY AREA

The study area shown in Figure 1 consists of a chain of lakes forming part of or draining to the Black River system in the District of Thunder Bay. The Black River has its origin north of the Improvement District of Manitouwadge and flows in a general southerly direction to its confluence with the Pic River which, in turn, discharges to Lake Superior near Heron Bay.

Two reference lakes, Wowun and Morley, were selected for the investigation as being representative of conditions in uncontaminated lakes on the Manitouwadge Chain. Wowun Lake is the largest of the study lakes, occupying a surface area of 600 acres with a maximum depth of 43 feet. Morley Lake is one of the smaller lakes included in the investigation, having a surface area of 232 acres and a depth of 14 feet. Both Wowun and Morley occupy headwater positions and, as such, are limited in water exchange to the drainage of their own small basins. No mill wastes have entered either lake.

The main body of Manitouwadge Lake covers a surface area of 330 acres and reaches a maximum depth of 32 feet. Like the reference lakes, Manitouwadge Lake occupies a headwater position and, therefore, has only limited water exchange.

Little Manitouwadge Lake is basically a restriction and subsequent widening of Manitouwadge Lake. It is the smallest of the study waters with a surface area of 146 acres and depths of 10 feet or less. Similarly, Little Mose Lake is a small shadow bog lake occupying a surface area of 216 acres with depths of 8 feet or less. Both lakes are downstream from Manitouwadge Lake and are contaminated with mining wastes.

Mose Lake is 250 acres in area with a

IMPROVEMENT DISTRICT OF MANITOUWADGE

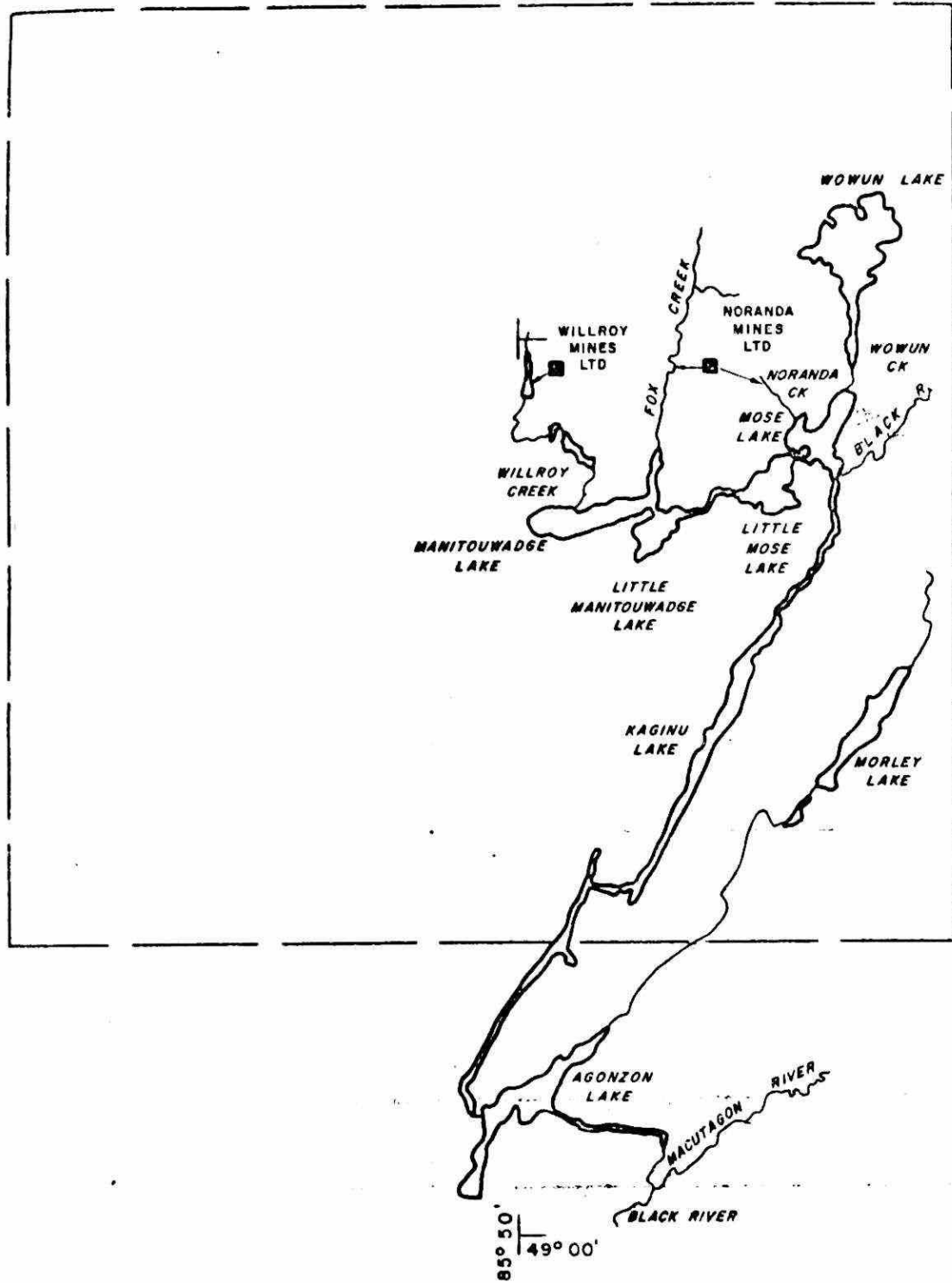


FIGURE I
MANITOUWADGE CHAIN OF LAKES

Kagu Lake
Agonzon Lake

322
360

19
29

maximum depth of 36 feet. Little Mose Lake empties into Mose Lake as does the Black River and the overflow from Wowun Lake.

The Lakes Kaguinu and Agonzon, by virtue of their downstream location, are both subject to the influence of mine waste contaminants displaced from Mose Lake. Kaguinu is a long and narrow lake which covers a surface area of 322 acres with depths of 19 feet or less. Agonzon, the last lake of the chain, has a surface area of 360 acres with a maximum depth of 29 feet.

For ease of reference, Table 1 below provides a summary of the areas and maximum depths of the study lakes.

Table 1. Morphometric characteristics of the Manitouwadge Lakes

	Surface area (acres)	Maximum depth (feet)
Morley Lake	232	14
Wowun Lake	600	43
Manitouwadge Lake	330	32
L. Manitouwadge Lake	146	10
L. Mose Lake	216	8
Mose Lake	250	36
Kaguinu Lake	322	19
Agonzon Lake	360	29

FINDINGS

Water Quality

Indication of the quality of water being

discharged to the study lake by way of the three contaminated creeks, Willroy, Fox and Noranda, is given in Table 2. For purpose of comparison, this table indicates the chemical quality of Wowun, an uncontaminated creek which flows into Mose Lake. The grossly impaired nature of Willroy and Fox Creeks and especially Noranda Creek is readily evident from these data. An even better appreciation of the degree to which the Manitouwadge Lake was being loaded with contaminants is gained by examining the volume of the waste discharge. At the time of the investigation, Willroy Mines Limited was discharging approximately 0.75 million gallons of water daily to Willroy Creek and operations at Noranda Mines Limited result in a daily waste decant of approximately 2.5 million gallons. The waste water decant to Willroy Creek receives approximately 1:1 dilution before reaching the monitoring point whereas little or no dilution occurs in Noranda Creek. This accounts for some of the difference in waste concentrations between Willroy Creek and Noranda Creek. The only significant difference in milling procedure between the two operations related to the use at Noranda Mines Limited of anhydrous ammonia for pH adjustment, a practice which was not being followed at Willroy Mines Limited during the survey period. This accounts for the staggering difference in free ammonia levels in Willroy Creek (.56 ppm) and Noranda Creek (21.13 ppm).

Comparative data on water quality of the eight study lakes are provided in Table 3. Assuming that prior to mining activity all of those lakes were similar in chemical composition to that of the uncontaminated Wowun Lake and Morley Lake, the data demonstrate marked changes in the chemistry of Manitouwadge and Mose Lake and significant impairment of each of the downstream lakes. Comparison of the similarities in chemical quality of the contaminated streams (Table 2) with the chemical quality of Manitouwadge Lake and Mose Lake (Table 3) add unquestionably to the credibility of the aforementioned assumption.

Critical water chemistry changes in Manitouwadge Lake and Mose Lake include gross alteration of their ionic composition, increased acidity, dissolved oxygen depletion (see Table 4) and elevations of heavy metals and ammonia content to acutely toxic levels. The chemical quality of both lakes is such that neither

Table 2. Water quality of Willroy, Fox and Noranda; three contaminated creeks and Wowun; a reference creek, which discharge to the Manitouwadge Lakes. Values listed are the average concentration in parts per million. The number of measurements is indicated in brackets.

	Wowun Creek	Willroy Creek	Fox Creek	Noranda Creek
Dissolved solids	125(3)	746(2)	180(2)	1588(2)
Sulphates (as SO ₄)	8(4)	367(3)	196(3)	1107(3)
Free ammonia (as N)	.17(4)	.56(4)	.99(4)	21.13(4)
Hardness (as CaCO ₃)	159(3)	380(3)	202(3)	747(3)
Alkalinity (as CaCO ₃)	78(4)	7.3(4)	38(4)	10.8(4)
Acidity (as CaCO ₃)	1(4)	3.3(4)	14.8(4)	85.5(4)
Iron (as Fe)	.06(4)	.42(4)	7.9(4)	23.9(4)
Zinc (as Zn)	.01(4)	.69(4)	.70(4)	3.41(4)
Copper (as Cu)	0.0(4)	.02(4)	0.0(4)	.26(4)

Table 3. Chemical properties of the surface waters of eight lakes in the Manitouwadge Chain. All values are recorded as the average concentration in parts per million. The number of measurements is provided in brackets.

	Wowun Lake	Morley Lake	Manitouwadge Lake	Little Manitouwadge Lake	Little Mose Lake	Mose Lake	Kaginu Lake	Agonzon Lake
Dissolved solids	101(3)	108(1)	303(11)	221(4)	212(4)	265(11)	184(4)	161(4)
Sulphates (as SO ₄)	9.3(3)	8(1)	146(12)	102(5)	97(5)	130(12)	80(5)	59(5)
Free ammonia (as N)	.07(3)	.03(1)	.30(12)	.17(5)	.19(5)	2.6(12)	.78(5)	.74(5)
Hardness (as CaCO ₃)	81(3)		240(8)	137(3)	137(3)	162(8)	118(3)	98(3)
Alkalinity (as CaCO ₃)	71(3)	49(1)	50(12)	47(5)	50(5)	43(12)	46(5)	39(5)
Acidity (as CaCO ₃)	1.3(3)	0(1)	4(12)	2.6(5)	2(5)	4.3(12)	2.6(5)	2.5(5)
Iron (as Fe)	.18(3)	.03(1)	1.88(12)	1.37(5)	1.09(5)	1.50(12)	.82(5)	.90(5)
Zinc (as Zn)	.02(3)	.05(1)	.54(12)	.29(5)	.25(5)	.43(12)	.18(5)	.20(5)
Copper (as Cu)	0.0(3)	.01(1)	.023(12)	.014(5)	.012(5)	.03(12)	.022(5)	.013(5)

Table 4. Vertical and seasonal changes in the temperature and dissolved oxygen profiles of Manitouwadge Lake and Mose Lake, 1970.

Date	MANITOUWADGE LAKE				MOSE LAKE			
	0'	10'	20'	30'	0'	10'	20'	30'
<u>Dissolved Oxygen (ppm)</u>								
10.2.70	8	7	7	7	6	6	1	<1
18.3.70	9	7	5	4	6	4	3	0
15.4.70	8	6	5	5	7	3	3	4
12.5.70	8	9	10	10	10	10	1	1
26.5.70	9	9	9	9	8	9	2	<1
12.6.70	9	9	8	7	8	9	1	0
23.6.70	8	8	8	6	8	8	0	0
18.7.70	8	8	7	3	9	8	0	0
30.7.70	6	6	6	2	6	6	0	0
13.8.70	8	8	6	2	7	7	0	0
26.8.70	7	5	5	1	7	5	0	0
5.10.70	8	7	7	7	8	7	0	0
2.11.70	8	7	7	7	7	7	5	<1
<u>Temperature (°F)</u>								
10.2.70	32	36	36	36	32	35	37	38
18.3.70	32	34	36	39	32	37	38	38
15.4.70	33	36	38	38	32	37	37	37
12.5.70	39	39	39	39	39	39	38	37
26.5.70	49	49	47	44	50	50	39	35
12.6.70	64	64	52	44	64	64	40	38
23.6.70	67	66	64	54	66	64	52	44
18.7.70	69	66	63	49	68	65	46	40
30.7.70	72	69	66	56	70	68	55	45
13.8.70	72	70	66	49	73	64	45	40
26.8.70	62	61	61	52	61	61	52	42
5.10.70	49	48	48	45	48	48	48	42
2.11.70	42	42	42	42	39	41	42	42

would be capable of supporting most of their indigenous fauna.

High metals and ammonia content persist throughout all of the downstream lakes. Little Manitouwadge Lake, Little Mose Lake, Kaguinu Lake and Agonzon Lake all contained concentrations of these contaminants which would be expected to exert sub-lethal effects on aquatic communities. These lakes probably could support resident populations of fish but poor production would be expected.

Early in the investigation it became evident that restoration of reference water quality was incomplete at Agonzon Lake. In order to discover the point at which normal quality returned, three sampling stations were added, their locations being Station 1, the Black River reference upstream from all contaminants; Station 2, Black River at Highway 614, and Station 3, Black River at Highway 17. Stations 2 and 3 were located approximately 15 and 60 river miles below Agonzon Lake, respectively.

Table 5 provides the results of chemical tests conducted on water samples secured from the three Black River sampling stations. These data show that restoration of baseline quality is incomplete at Highway 614 crossing but satisfied for the most part at Highway 17. Even at the latter location, however, high ammonia values persisted. Dilution provided by the inflowing tributaries Macutagon, Mobart, Bearhead, Cedar and Swede would account for the recovery observed.

Comparison between Manitouwadge and Mose

In the preceding section, the surface water quality of the study lakes was examined in order to relate changes in their quality to the points of waste inputs. One interesting feature of these data (Table 3) was the poor quality of the surface waters of Manitouwadge, Little Manitouwadge and Little Mose in comparison to the surface water quality of Mose, Kaguinu and Agonzon. The reverse situation would be expected since Mose Lake receives nearly four times the volume of wastes that discharge to Manitouwadge Lake. The reason for this apparent discrepancy can be seen in

Table 5. Water quality of the Black River upstream and below the sources of mine wastes. Values listed are the average concentration in parts per million. The number of determinations is provided in brackets.

	Black River No. 1	Black River No. 2	Black River No. 3
Dissolved solids	135 (3)	163 (3)	138 (1)
Sulphates (as SO_4)	8 (4)	25 (4)	14 (1)
Free ammonia (as N)	.04 (4)	.14 (4)	.16 (1)
Hardness (as CaCO_3)	67 (3)	123 (3)	82 (1)
Alkalinity (as CaCO_3)	83 (4)	95 (4)	64 (1)
Acidity (as CaCO_3)	4 (4)	1 (4)	5 (1)
Iron (as Fe)	.15 (4)	.09 (4)	.20 (1)
Zinc (as Zn)	.005 (4)	.012 (4)	0.0 (1)
Copper (as Cu)	0.0 (4)	.018 (4)	0.0 (1)

Table 6 which explores the vertical quality of the two lakes. While the water chemistry of Manitouwadge Lake is fairly consistent throughout the water column, a marked chemical gradient occurs with depth in Mose Lake. If one examines the seasonal changes in the vertical composition of sulphates in these lakes (Table 7), it will be noted that Manitouwadge Lake experiences the normal seasonal processes of stratification and destratification. Through these processes, contaminants which enter the lake are mixed throughout the entire water mass so that some of the wastes would leave the lake as overflow. In contrast, the seasonal pattern of sulphate distribution in Mose Lake demonstrates that the lake is meromictic, that is to say, the lake remains in a continual state of stratification. This condition develops when dissolved solids create a gradient of density differences from surface to bottom which prevents mixing or circulation of water. Conditions of meromictic stability, while uncommon, have been described for several lakes on the European Continent. One of these, Lake Ritom in Switzerland, is a classical example of a type of meromixis referred to as crenogenic (Hutcheson, 1957) which results from saline springs delivering dense sulphate-rich waters into the depths of the lake. In a similar manner, the dense sulphate-rich waters delivered to Mose Lake via Noranda Creek (1,100 ppm sulphates) have undoubtedly induced the condition of crenogenic meromixis.

The condition in Mose Lake has the effect of trapping and concentrating mining wastes in the bottom waters. This accounts for the gross chemical contamination detected in Mose Lake below the ten foot depth and explains, as well, why the chemical quality of Kaguinu and Agonzon is better than would be expected.

Acid Formation

Failure of pH adjustment at the point of discharge to prevent subsequent acid formation is a common problem associated with the handling of sulphuric mining wastes. Considerable information is available in the literature describing the mechanisms involved in acid generation. Reference to Barnes (1968) Schmidt and Conn (1969) and Hawley and Shikaze (1971) is suggested for specific details of the

Table 6.

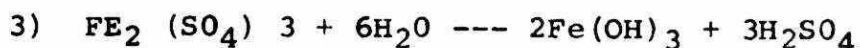
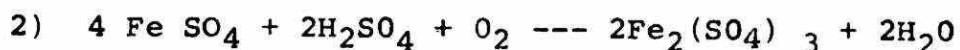
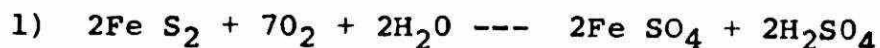
Comparison of the vertical chemical properties of Manitouwadge Lake and Mose Lake. Values recorded indicate the average concentration derived from twelve measurements from February to November, 1970.

	Manitouwadge Lake				Mose Lake			
	0'	10'	20'	30'	0'	10'	20'	30'
Dissolved solids	303	308	349	393	265	507	1158	1494
Sulphates (as SO_4)	146	154	178	205	130	292	725	988
Free ammonia (as N)	.30	.28	.34	.39	2.6	10.7	32	46
Total Kjeldahl (as N)	.64	.66	1.21	.79	3.3	11.6	34	48
Nitrite (as N)	.008	.009	.024	.044	.008	.045	.019	.033
Nitrate (as N)	.17	.18	.21	.31	.18	.22	.09	.13
Total phosphorus (as P)	.033	.038	.162	.066	.06	.055	.043	.024
Hardness (as CaCO_3)	204	215	239	276	162	315	550	723
Alkalinity (as CaCO_3)	50	48	46	47	43	33	7.2	10.5
Acidity (as CaCO_3)	4	3.3	4.5	5.4	4.3	17	73	88
Iron (as Fe)	1.88	1.88	1.95	1.57	1.5	3.96	24	27.1
Zinc (as Zn)	.54	.57	.70	.76	.43	.69	1.52	1.39
Copper (as Cu)	.023	.02	.02	.025	.03	.05	.07	.19
Sodium (as Na)	7.2	7.9	8.8	12	5.4	16	31.4	.38
Potassium (as K)	2.66	2.8	3.1	3.9	2.8	8.9	15.7	27.5
Calcium (as Ca)	65	68	74	97	47	94	147	191
Magnesium (as Mg)	10.3	9.3	10.3	8.3	8	15	16.5	24

Table 7. Seasonal and vertical changes in sulphate levels, Manitouwadge Lake and Mose Lake, 1970. Results are expressed as parts per million sulphates.

Date	MANITOUWADGE LAKE				MOSE LAKE			
	0'	10'	20'	30'	0'	10'	20'	30'
February 10	115	150	280	320	170	790	910	915
March 18	173	220	300	470	140	810	910	1070
April 15	190	230	280	340	160	725	500	850
May 12	<u>160</u>	<u>150</u>	<u>170</u>	<u>160</u>	<u>160</u>	<u>160</u>	<u>975</u>	<u>1125</u>
May 26	145	150	155	170	100	105	330	775
June 12	120	120	120	140	90	100	880	1000
June 23	140	136	144	164	100	96	750	1150
July 18	139	124	129	139	105	106	690	940
July 30	130	120	110	120	110	125	580	1130
August 26	190	190	194	184	210	206	750	1300
October 5	128	128	132	128	120	164	960	880
November 2	<u>124</u>	<u>124</u>	<u>124</u>	<u>124</u>	<u>100</u>	<u>116</u>	<u>460</u>	<u>720</u>

chemistry involved. For the purpose of this report, the process can be described in the following simplified equations:



All too frequently, total oxidation of soluble iron and sulphur species (along with other unoxidized substances) is not achieved at the point of discharge so that continued oxidation in the receiving water causes subsequent pH depression.

Evidence of acid generation in Mose Lake and, to a lesser extent, in Manitouwadge Lake is provided in Table 8 which compares the vertical and seasonal changes in alkalinity, acidity and pH of the two lakes. The pH value provides a measure of the hydrogen ion content of the water, while alkalinity readings measure the capacity of the water to neutralize hydrogen ions. The total acidity value is a measure of the total quantity of hydrogen ions which would be liberated during the oxidation and hydrolysis of the various cations in solution.

In Manitouwadge Lake, the low pH readings which occurred on April 15th, May 12th and July 30th suggest acid generation; however, this is probably not a critical situation in Manitouwadge Lake since the potential for hydrogen ion production, as measured by total acidity, is quite low and fairly good buffering would be expected on the basis of the alkalinity readings secured from the lake. In contrast, the waters of Mose Lake appear to be the site of considerable acid formation. Measurements of pH, alkalinity and acidity taken from the 20 and 30 foot depths in Mose Lake, demonstrate that these waters have a high hydrogen ion content indicative of past acid formation, no reserve buffering capacity and a high potential for further hydrogen ion liberation.

Further indication of acid production occurring in Mose Lake was obtained by bacteriological examination of water samples for the bacterium.

Table 8. Comparison of the vertical and season changes in Alkalinity, acidity and pH in Manitouwadge Lake and Mose Lake, 1970.

Date	Alkalinity as CaCO ₃ (ppm)				Acidity as CaCO ₃ (ppm)				pH			
	0'	10'	20'	30'	0'	10'	20'	30'	0'	10'	20'	30'
<u>Manitouwadge Lake</u>												
Feb.10	47	46	44	39	5	5	5	5	7.3	7.5	7.8	7.4
Mar.18	68	58	52	52	7	7	14	10	6.8	6.8	6.6	6.5
Apr.15	64	54	28	42	4	6	6	6	6.3	6.1	6.6	6.4
May 12	44	46	44	44	4	4	4	4	6.0	6.4	5.5	5.8
May 26	42	42	42	42	4	2	2	4	6.7	6.8	6.8	6.8
June 12	46	46	44	42	3	3	6	6				
June 23	46	46	46	46	2	2	4	4	6.7	6.7	6.8	6.8
July 18	52	47	49	49	4	3	3	4				
July 30	52	47	47	47	1	1	2	8	5.9	6.2	6.3	6.4
Aug. 26	54	55	54	58	2	3	3	9	7.7	7.7	7.8	7.3
Oct. 5	50	53	48	53	3	2	2	2	7.6	7.7	7.6	7.7
Nov. 2	32	36	50	54	3	2	3	3	7.3	7.4	7.4	7.4
<u>Mose Lake</u>												
Feb.10	42	2	4	4	11	34	169	154	7.0	5.2	4.9	5.1
Mar.18	64	8	16	16	7	75	95	100	6.8	6.3	5.8	5.7
Apr.15	82	6	20	24	6	67	49	63	6.2	5.6	5.8	5.6
May 12	33	33	4	4	4	4	101	70	5.9	6.4	5.9	5.6
May 26	37	37	6	0	4	4	16	78	6.0	6.6	5.8	6.0
June 12	46	44	0	4	4	4	88	84				
June 23	49	46	2	2	2	2	73	74	7.0	7.0	5.6	5.1
July 18	47	45	0	0	3	3	78	69				
July 30	43	43	0	4	1	1	44	86	6.5	6.5	6.0	5.7
Aug. 26	45	44	0	12	5	4	22	106	7.5	7.6	4.8	5.6
Oct. 5	46	42	22	18	2	2	109	110	7.5	7.6	5.7	3.9
Nov. 2	64	46	12	38	3	5	33	66	7.4	7.3	6.2	6.2

variety and abundance of macroinvertebrate bottom fauna. This factor poses no

Thiobacillus thiooxidans, an important biological agent in the oxidation of ferrous ions to ferric ions. On February 10, the surface waters of Mose Lake contained 11,000 of these bacteria per ml. On the same date, a much lower count of only 240 per ml. was recorded from a surface water sample taken from Manitouwadge Lake. The deeper waters of both lakes had much lower densities of T. thiooxidans than were present at the surface. At a depth of twenty feet, the respective counts in Manitouwadge Lake and Mose Lake were 43 and 2,100 bacteria per ml. Reductions in dissolved oxygen at the twenty foot depths would account for the lower numbers of T. thiooxidans, since the bacteria require oxygen to live. On the sampling date, surface water levels of oxygen in Manitouwadge and Mose were 9 and 6 ppm, respectively, whereas the corresponding levels were 5 and 3 ppm at the 20 foot depths.

Sediment Chemistry

Creek and lake sediments were sampled on several occasions in order to determine the extent of metal buildup and downstream transport. The results of sediment chemistry analyses are provided in Table 9.

Sediments from the uncontaminated reference waters contained only trace levels (150 ppm) of zinc, copper and lead; on the other hand, these same metals were major components of the sediments of Mose and Manitouwadge Lakes. From six sets of results, the respective maximum concentrations in Manitouwadge and Mose muds were: 8,860 and 7,120 ppm zinc, 1,234 and 3,480 ppm copper and 662 and 476 ppm lead. Lakes downstream from Manitouwadge and Mose had only slightly elevated levels of copper and lead in their sediment but high zinc occurred in all of these lakes, including Agonzon, the most remote body from the two sources of contaminants.

Bottom Fauna

Lakes of Northern Ontario are inherently limited both with respect to variety and abundance of macro-invertebrate bottom fauna. This factor poses no great difficulty in the investigation of organic pollution

Table 9. Results of chemical analyses performed on sediment samples collected from streams and lakes of the Manitouwadge Chain during 1970. Values given are average for the number of samples indicated.

	No. of Samples	% Loss on Ignition	Zinc as Zn (ppm)	Copper as Cu (ppm)	Lead as Pb (ppm)	Manganese as Mn (ppm)	Iron as Fe (%) **
Wowun Creek*	1	11.8	<150	<150	<150	<150	1.06
Willroy Creek	2	19.6	680	700	160	323	3.41
Fox Creek	1	26.0	4600	1344	252	364	7.75
Noranda Creek	1	22.4	868	552	<150	170	7.22
Wowun Lake*	2	13.9	<150	<150	<150	307	2.27
Morley Lake*	1	34.7	<150	<150	<150	258	1.48
Manitouwadge Lake (mouth of Willroy Cr.)	2	15.9	3000	564	<150	520	2.53
Manitouwadge Lake (Fox Bay)	2	30.1	7080	2313	247	366	12.70
Manitouwadge Lake	6	19.6	4505	791	<150	417	3.0
Little Manitouwadge Lake	4	15.9	675	<150	<150	303	2.31
Little Mose Lake	4	16.5	1660	167	<150	272	2.48
Mose Lake	6	24.0	3985	1955	164	343	5.52
Kaginu Lake	4	21.3	1663	222	<150	347	2.87
Agonzon Lake	4	23.5	1443	156	<150	422	2.82

* Control creek and lakes

** 1% is equivalent to 10,000 ppm.

on its descent through the epilimnion to the lake bottom. Assuming this is to be true, then only two individuals, both midges of the family Tendipedidae, were

which tends to restrict variety but increase the numbers or organisms in the affected community. However, inorganic pollution such as that resulting from acid-mine wastes has a restrictive influence on the bottom fauna community both with respect to variety and abundance so that the net effect of acid-mine pollution is to impose further restrictions on an inherently unproductive community.

Figure 2 depicts the lake to lake distribution and densities of bottom fauna collected from the Manitouwadge Chain of Lakes during 1970. These data are provided in summarized form in Table 12 below.

Table 12. Variety and abundance of bottom fauna collected from eight lakes of the Manitouwadge Chain, 1970

Lake	Variety (No. of Taxa)	Density (No. of Organisms/ft. ²)
Wowum	7	37
Morley	8	29
Manitouwadge	5	12
Little Manitouwadge	5	16
Little Mose	8	25
Mose	2	1
Kaginu	6	17
Agonzon	4	26

Mose Lake provides a spectacular example of severe acid-mine pollution and its effect on benthic production. Eleven of fifteen sediment samples taken from Mose Lake were void of life and the yield

WOWUN

HEXAGENIA (P)

TENDIPEDIDAE (31)

HELEINAE (P)

CHAOBORUS (5)

VALVATA (P)

L. SILIQUIDEA (P)

TUBIFICIDAE (P)

MOSE

TENDIPEDIDAE (P)

CHAOBORUS (P)

KAGINU

SIALIS (P)

TENDIPEDIDAE (11)

HELEINAE (P)

CHAOBORUS (5)

GLOSSTIPHANIIDAE (P)

TUBIFICIDAE (P)

MANITOUWADGE

CHEUMATOPSYCHE (P)

TENDIPEDIDAE (11)

HELEINAE (P)

CHAOBORUS (P)

TUBIFICIDAE (P)

LITTLE MANITOUWADGE

OECETIS (P)

TENDIPEDIDAE (14)

HELEINAE (P)

CHAOBORUS (P)

TUBIFICIDAE (P)

MORLEY

HEXAGENIA (7)

PHYLOCENTROPUS (1)

SIALIS (P)

TENDIPEDIDAE (4)

HELEINAE (P)

CHAOBORUS (14)

PISIDIUM (2)

ANODONTA GRANDIS (P)

LITTLE MOSE

HEXAGENIA (P)

OECETIS (P)

POLYCENTRIPUS (P)

TENDIPEDIDAE (20)

HELEINAE (P)

CHAOBORUS (3)

SPHAERIUM (P)

TUBIFICIDAE (P)

AGONZON

TENDIPEDIDAE (24)

CHAOBORUS (1)

PISIDIUM (P)

TUBIFICIDAE (P)

FIG 2. DISTRIBUTION AND ABUNDANCE OF MACROIN VERTEBRATES COLLECTED FROM THE MANITOUWADGE CHAIN OF LAKES, 1970. NUMBERS IN BRACKETS INDICATE DENSITY OF THE ORGANISM PER FT². "P" SIGNIFIES ORGANISM PRESENT IN DENSITY OF LESS THAN ONE PER FT².

from the remaining four samples was a mere five specimens, three of which were phantom midges of the genus Chaoborus, a planktonic form which in all likelihood were taken by the dredge on its descent through the epilimnion to the lake bottom. Assuming this is to be true, then only two individuals, both midges of the family Tendipedidae, were present per 8.1 ft.² (fifteen Ekman dredge samples) of Mose Lake sediments. The same effort on the reference lakes Wowun and Morley produced respective yields of 7 and 8 taxa and densities of 37 and 29 organisms per ft.².

Manitouwadge Lake, which contains a greater volume of water than Mose Lake and receives a lesser volume of mine wastes, yielded five taxa of macroinvertebrates and a density of 12 organisms per ft.². While considerably healthier than the Mose Lake community, this still represents an impoverished community in comparison with those of the reference lakes.

Little Manitouwadge Lake contained a community comparable to that of Manitouwadge Lake, its source, except for a slightly higher standing crop of 16 organisms per ft.². Both of these lakes contained taxa which Parsons (1968) and Katz (1969) found to exhibit tolerance to acid-mine pollution and neither lake yielded specimens of mayflies Hexagenia sp. or the unionids Lampsalis siliquoidea and Anadonta grandis which were listed by the same authors as being intolerant of acidmine wastes. All three of these forms were present in the control lakes Wowun and Morley.

The benthos of Little Mose Lake, which is situated downstream from Little Manitouwadge Lake, provides evidence of improved water quality. The bottom fauna community of Little Mose Lake compared favourably with the control lakes both with respect to variety and number of organisms present. Mayflies of the genus Hexagenia were present in Little Mose Lake but no unionid clams were taken.

Kaginu Lake, downstream from Mose Lake, contained a bottom fauna association similar in most respects to that of moderately polluted Manitouwadge

Lake. Agonzon, the final downstream lake, contained a low number of taxa but produced a density of 26 organisms per ft.² which is close to the density found in the reference lakes. Hexagenia and unionid clams were absent from both Kaginu and Agonzon.

SUMMARY AND CONCLUSIONS

The study has shown serious impairment of water quality and associated effects on aquatic life of several lakes in the Black River System. The lakes most seriously impaired were Mose and Manitouwadge which receive the respective waste discharges from Noranda Mines Limited (Geco Division) and Willroy Mines Limited.

In Mose Lake, the continuous input of wastes of high dissolved solids content has resulted in the establishment of a density gradient with depth which prevents the lake water from mixing. As a result, conservative components of the wastes have become trapped and concentrated to critical levels in the bottom waters of the lake. Specifically, the problems identified in Mose Lake were:

- 1) acid generation and pH depression
- 2) total de-oxygenation of waters below the twenty foot level
- 3) toxic concentrations of ammonia, zinc, copper and iron
- 4) excessive nitrogen enrichment
- 5) exceptionally high concentrations of dissolved solids, particularly sulphates
- 6) major accumulations of zinc, copper, lead and iron in the lake sediments
- 7) total elimination of bottom dwelling macroinvertebrates, an important link in the aquatic food chain.

While a density gradient had not materialized in Manitouwadge, the lake had, to a lesser extent, the same water quality problems as found in Mose Lake. The downstream lakes - Little Manitouwadge, Little Mose, Kaguinu and Agonzon, were all discovered to contain concentrations of dissolved solids, metals and ammonia which were considerably higher than background levels in the reference lakes, Wowun and Morley.

The study described provides an indication of the environmental problems facing the mining industry in the Manitouwadge and other areas of the Province. Finding the solution to these problems provides a major challenge to Ontario's fastest growing resource based industry.

REFERENCES

- Barnes, H.L. and Romberger, S.B. 1968. Chemical aspects of acid mine drainage J.W.P.C.F. V40(3): 371-84
- Hawley, J.R. and K.M. Shikaze. 1971. Problem of Acid Mine Drainage in Ontario. Presented at the 18th Ontario Industrial Waste Conference, June 13-16, 1971, Niagara Falls, Ontario
- Hutchinson, G.E. A treatise on limnology. Volume I. New York, John Wiley and Sons Inc. 1015 pp.
- Schmidt, J.W. and K. Conn, 1969. Abatement of pollution from mine wastewaters. Canadian Mining Journal June, 1969. 54-60.

"Toxicity Studies Relating to
Acidic Conditions in Lake Systems"

BY

G. R. CRAIG

Limnology & Toxicity Section

Water Resources Branch

Ministry of the Environment



G. R. CRAIG

In recent years, the apparent incompatibility of industrial development with conservation of the natural environment has stimulated concern for the protection of renewable resources. Of particular interest to Ministry of the Environment biological staff has been the decline of sport and commercial fisheries in certain Northern areas, apparently associated with man's intensified industrial activities. The mining of base and precious metals has had a demonstrable direct effect on surface waters in large tracts of Northern Ontario. We shall concern ourselves here with the indirect effect, less easily demonstrable, of the processing of metals and the resultant release of potential pollutants, and their interaction with surface waters. The purpose of the studies outlined here is not to elucidate the mechanics of the process but to delineate the effects on aquatic biota, specifically fish.

Beamish and Harvey (1972) studying lakes within the La Cloche Mountains southwest of Sudbury reported loss of populations of lake trout, lake herring and white sucker in Lumsden Lake (Table I).

During the same interval of declining fish populations Lumsden Lake also underwent a considerable reduction in pH. The mean annual decrease of pH in 22 additional lakes studied, in and in close proximity to the La Cloche Mountains, was 0.16 units over the same period. Individual lakes showed dramatic decreases in pH within the 10-year study span (Table II). pH values as low as 4.0 were recorded.

Fish mortalities can be expected at values below pH 5.0, although it has been reported that some species

have become acclimated to values as low as pH 3.7 (E.I.F.A.C., 1963). Preliminary work done by Ontario Ministry of the Environment staff at Lake Panache just west of Sudbury, in 1973, indicated that 96-hour exposure of small-mouth bass and American flagfish, *Jordanella floridae*, to depressed pH conditions produced mortality at pH 4.0. The estimated median lethal value for both species was pH 3.7. Previous studies performed at George Lake, Killarney Provincial Park by Ontario Ministry of the Environment staff in 1971 - 72 found very similar results for yellow perch and lake trout. Repeated flow-through bioassays with George Lake water established, however, that lake trout from Sandfield hatchery Manitoulin Island could not be successfully acclimated to water of hardness 15 ppm and a pH of 5.1. Interestingly enough, survival of lake trout previously acclimated to modified George Lake water of pH approximate to 7, was better at pH 4.5 - 4.7 than at the accustomed pH of George Lake water previously mentioned (5.0 - 5.1). (Unpublished communication, Fallis, Innis). While the explanation of this phenomenon remains unclear, it possibly relates to the complex physical-chemistry of carbon dioxide which is greatly dependent on pH and which may directly affect respiratory processes at the gillwater interface.

Evidence accumulated over the past 20 years has tended to indicate that criteria more useful for management purposes may be derived from long-term studies at toxicant levels which allow the survival of adult fish but which may indirectly affect populations through effects on food supply or direct reproductive impairment. For this reason, studies should include more than one stage in the life-cycle of test organisms and, optimally, observations should be made over the entire life-cycle from egg-to-egg, under the full range of test conditions. An unsuccessful attempt was made to meet these prerequisites with yellow pickerel as a test species at George Lake in 1972. Unfortunately, a combination of logistic difficulties, fungusing of the eggs and the oft-reported variability in hatching success (under artificial conditions) made the results inconclusive.

In view of the lengthy periods of time required in indigenous species to complete a life-cycle, and the logistic problems thereby incurred, an attempt was made to find an alternative species which would be both oviparous and easy to culture, with as short a life-cycle as possible. The fathead minnow, used extensively by Mount and others, is of little commercial or ecological importance in the Precambrian Shield area and its six-month life-cycle would have presented difficulties arising from the shortness of the summer working season at these latitudes. Hence, the use of the American flagfish, which lends itself well to life-cycle bioassay and is capable of completing a life-cycle in 8 - 12 weeks (Smith 1973). In conjunction with the *Jordanella* experiments Dr. Ozburn at Lakehead University, Thunder Bay, Ontario, has been granted a contract to

examine the effects on pH depression on the brook trout, Salvelinus fontinalis, over a 1-2 year period, in the laboratory. A simultaneous experiment with Jordanella will be performed. The results of this study should afford a basis of comparison, indexing the results of the Lake Panache experiment and the Jordanella laboratory results to an indigenous fish, and giving weight to projected series of Jordanella experiments on lakes of different pH levels in the Sudbury region. Mount, under laboratory conditions, using the fathead minnow, has demonstrated the relationship between pH and egg-production in relatively hard water (Mount 1973). He indicated that, at pH of 5.2, females, although egg-laden, did not spawn. At a higher pH of 5.9, the number of eggs laid were reduced as compared to controls and all eggs were abnormal, tending to be fragile and lacking turgidity (Table III). Due to the poor egg quality at pH 5.9, hatchability was also reduced. No abnormal egg effects were observed at pH 6.6. While the effect of low pH on the eggs was considerable in the lower ranges, adult mortality was not significantly increased at any pH level, relative to the controls. These recent findings of Mount lend strength to the Ministry's decision to use the American flagfish to conduct a series of life-cycle tests, using lakewaters from the Sudbury area. It should be possible to demonstrate, thereby, the relationship between pH levels and the capacity of a lake to maintain a viable fish population. It will be necessary, of course, to chronic life-cycle testing using lakewaters chosen for their different chemical characteristics to examine the interaction of low pH and elevated metal concentrations. Further evidence of the significance of pH as a prime factor in the attrition of fish populations through reproductive impairment, as opposed to acute toxicity, has been accumulated by Almer in Sweden. Lakes receiving the acid waste-products of industrial processes have been reported as losing their populations of sunfish, perch, pike, cyprinids, brown trout and arctic char. Reproductive impairment occurred at levels just below pH 5.5, a level which is not likely to cause acute toxicity. This agrees closely with Mount's experimental results.

The ecological balance of soft-water lakes is far more easily upset by acidification than that of hard-water lakes due to the inherent fragility of the food-chain itself and, more particularly, to the reduced pH buffering capacity. The introduction of pH-depressing agents, by whatever means, will result in a more marked pH drop in the soft-water situation. Graph I depicts the pH response, on addition of concentrated sulphuric acid, of Toronto tap-water of hardness approximately 140 ppm as CaCO_3 , as compared to that of Lake Panache with a hardness of circa 30 ppm.

The study of Lake Panache, currently in progress, is designed to determine the level of pH that is detrimental to the reproduction and development of the American

flagfish, Jordanella floridae. The Lake Panache site was selected for its proximity to the Sudbury metal-smelting complex, its favourable water quality characteristics (normal pH, stable fishery, hardness, alkalinity and metal levels, displaying uncontaminated characteristics), its accessibility for the mobile laboratory and the availability of power and storage facilities.

Flagfish eggs are about one mm in diameter and are deposited in the test aquaria on a green, wool-covered substrate. The adults come into breeding condition at a temperature at 25° C when subjected to a photoperiod of 16 hours, with simulated dawn and dusk dimming periods. The eggs are removed from the substrates and incubated in egg baskets under identical experimental conditions. Developing eggs and fry may be removed for microscopic examination to ascertain the extent of abnormal development, should this occur. Dead eggs are removed to prevent the spread of fungus.

The controls and four duplicate pairs of test aquaria are supplied with water and toxicant by a modified version of a proportional diluter after Mount and Brungs, 1967. An automated pipettor meters a solution of sulphuric acid into a mixing chamber which supplies the proportional diluter. A combined mixing-chamber and flow-splitter then delivers equal quantities of solution to each of the ten test aquaria. A flow rate of 6 litres per hour per tank is maintained. pH values for this experiment are nominally 4.5, 5.0, 5.5, and 6.0 with the control at pH 6.8.

The Lake Panache experiment is conducted in the Mobile Toxicity Laboratory of the Ministry of the Environment which has been under development since 1970. The experimental set-up with its extensive plumbing and control apparatus is shown in Diagram I.

To a considerable extent the toxicity studies described are experimental, both with respect to procedure and methodology. Many of the techniques employed are untried, particularly under field conditions. Consequently, this portion of the Ministry's Sudbury program is regarded as supplemental to the other studies currently underway in this region. The results obtained will be interpreted in the light of chemical, physical, hydrological and geological data obtained by specialist groups within the Ministry and by other participating agencies. Should the toxicity studies prove successful they will help to bridge the gap between existing laboratory data and empirical observations made under field conditions.

Table I: Fish populations in Lumsden Lake

Species	1966	1967	1968	1969	1970
Sucker	179	315	3	NC	NC
Herring	37	1323	212	6.5	NC
Trout	NC*	1	NC	NC	NC

From Beamish & Harvey (1972) pp. 1133

* Active fishery until 1965
NC None caught

Table II: Changing pH in Northern Ontario Lakes

Lake	1961	1969	1971
Lumsden	6.8	-	4.4
George	6.5	-	4.7
Sunfish	6.8	-	4.4
Freeland	-	5.2	4.8

From Beamish & Harvey (1972) pp. 1135

Table III: Reduced Fathead Minnow Reproductions in Low pH

Norman pH	4.5	5.2	5.9	6.6	Cont (7.5)
% Survival	80	75	85	75	85
Spawnings/♀	0	0	1.1	3.5	4.8
% Hatch	-	-	42	80	79
No. Eggs/♀	-	-	83	320	720

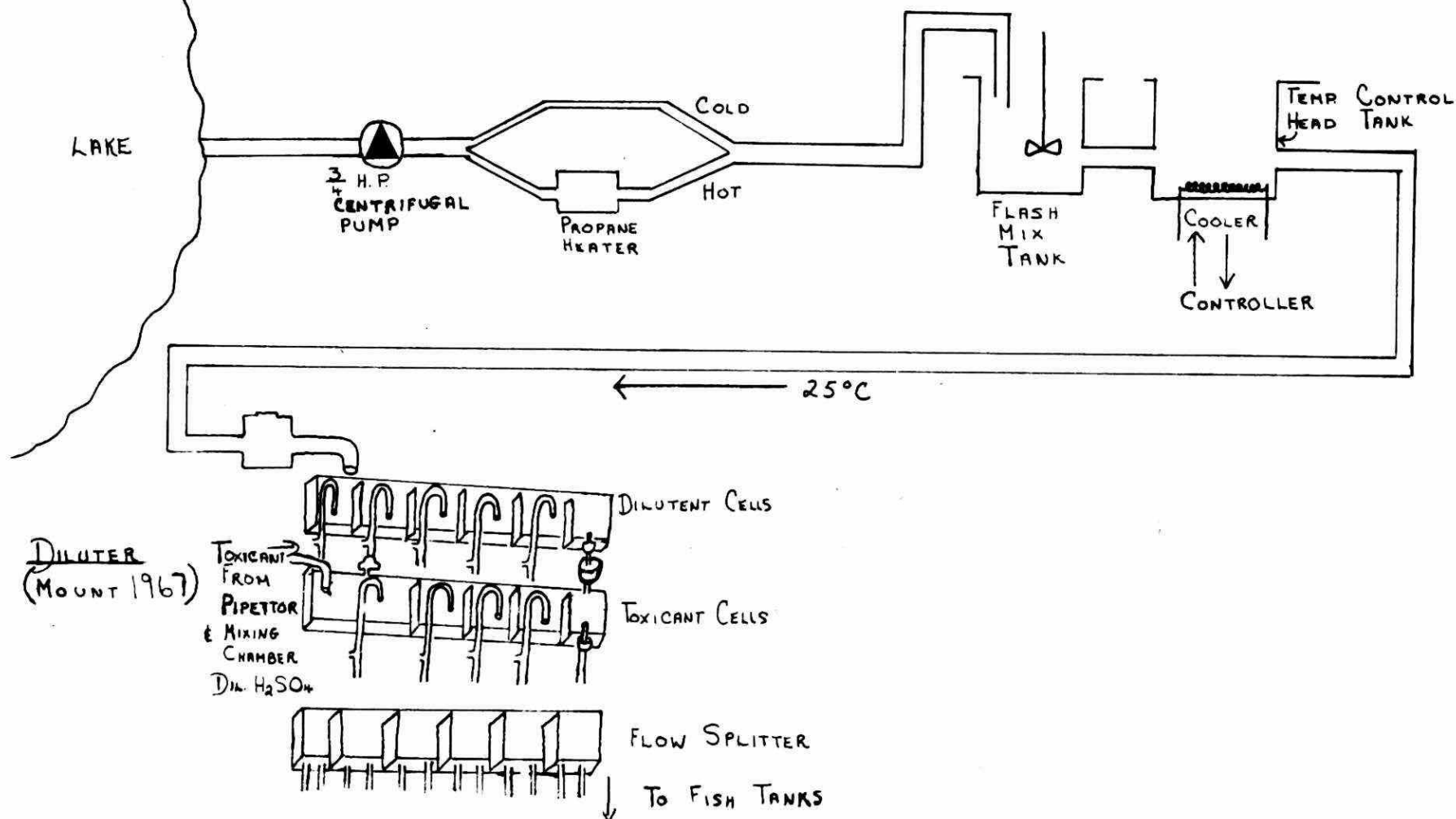
From Mount (1973) pp. 991

REFERENCES

- Almer, B. 1974
Effects of Acidification on Swedish Lakes
Ambio 3: 30 - 36
- Beamish, R.J.; H.H. Harvey 1972
Acidification of the La Cloche Mountain Lakes, Ontario, and resulting fish mortalities
J. Fish. Res. Bd. Can. 29: 1131 - 1143
- European Inland Fisheries Advisory Commission 1962
Water Quality Criteria for European Fresh Water Fish - Report on Extreme pH Values and Inland Fisheries
- Mount, D. I. 1973
Chronic Effect on Low pH on Fathead Minnow Survival, Growth and Reproduction
Water Research 7: 987 - 993
- Mount, D. I.; W. A. Brungs 1967
A Simplified Dosing Apparatus for Fish Toxicity Studies
Water Research 1: 21 - 29
- Smith, W. E. 1973
A Cyprinodontid Fish, Jordanella floridae, as a Laboratory Animal for Rapid Chronic Bioassays
J. Fish. Res. Bd. Can 30: 329 - 330

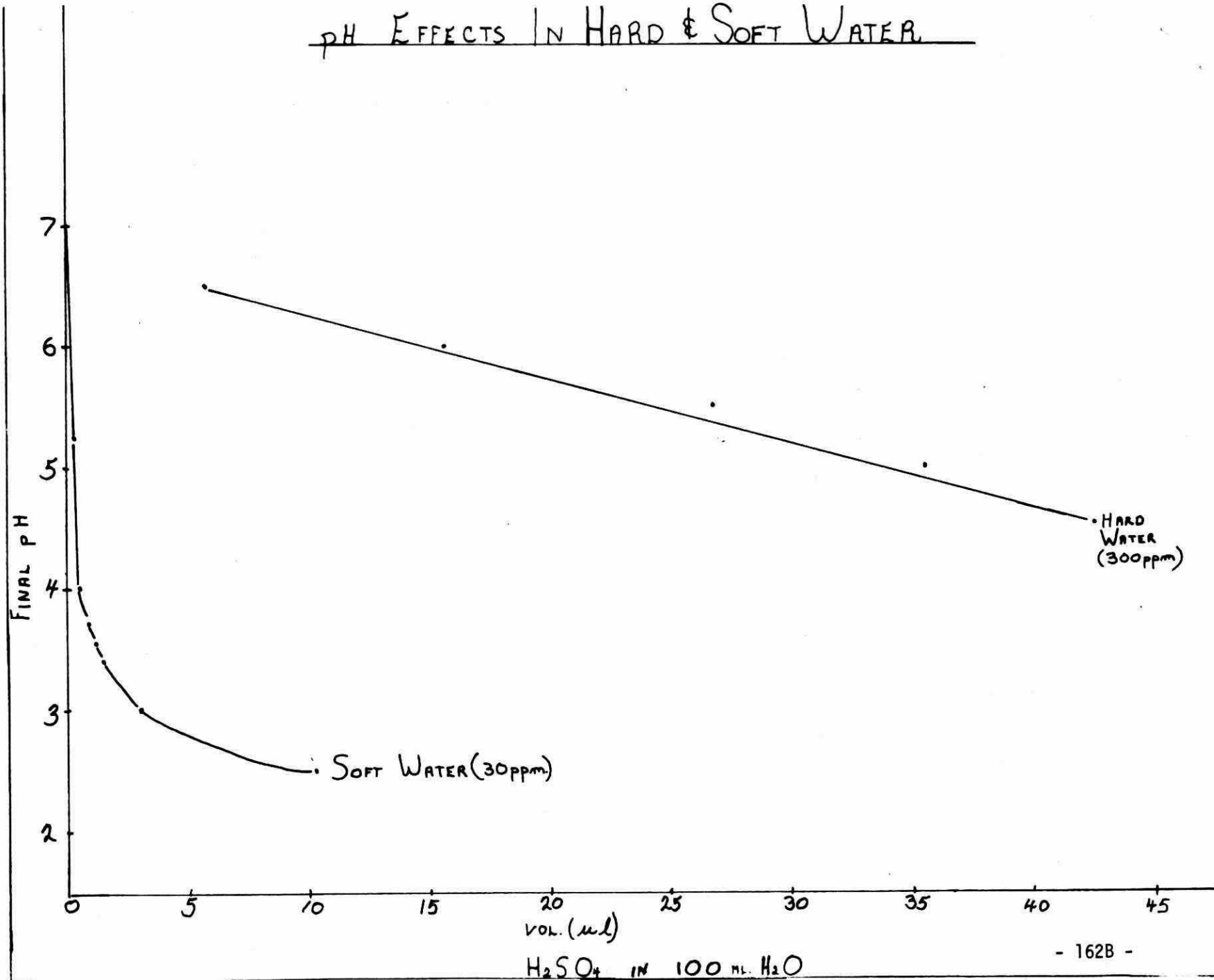
Prepared by G. Craig, C. Inniss 1974

DIAGRAM I FOR TEMPERATURE CONTROL SYSTEM-MOBILE TOXICITY
LABORATORY - L. PENAGE - 1974 (AMERICAN FLAG FISH REPRODUCTIVE STUDY)



GRAPH 1.

pH EFFECTS IN HARD & SOFT WATER





M.F.P. MICHALSKI

"Restoration of Acidified Lakes,
Middle and Lohi, in the Sudbury
Area"

BY

M. F. P. MICHALSKI

Supervisor

Limnology & Toxicity Section
Water Resources Branch
Ministry of the Environment

and

J. ADAMSKI

Scientist

Water Quality Section
Ministry of the Environment

As part of the Sudbury Environmental Study and in co-operation with fisheries staff of the Ministry of Natural Resources, efforts were initiated during the summer of 1973 to examine the feasibility of offsetting acidified conditions in order to restore the fisheries of selected lakes. This document presents some of the preliminary limnological highlights observed following pilot-scale treatments of Lakes Middle and Lohi with neutralizing substances and comments on the findings with a view to achieving ultimately the aforementioned management objectives.

Historically, the addition of neutralizing agents such as calcium hydroxide to alter lake water chemistry with a view to improving productivity is not a new technique (for example, see Ness 1949, Ball 1948, Moyle 1949, Thomaston and Zeller 1961, Hasler, Bryneldson and Helm 1951 and Waters 1956). Bowling and Busbie's (1964) three year study on three Georgia farm ponds was especially important as bottom dwelling organisms as well as phytoplankton stocks improved immeasurably following lime applications. Unpublished studies in Norway point out that the neutralization potential of calcium hydroxide is significantly reduced if applied on the surface of ice (calcium hydroxide is gradually converted to calcium carbonate when exposed for lengthy periods to the atmosphere). In the Sudbury area of the Province, Morris attempted to neutralize Clearwater Lake during the summer of 1958; however, our 1973 data for the lake indicated an extremely acidic condition, suggesting that the long-term effects of a "single-dose operation" are minimal.

Significantly, the author concluded that calcium carbonate was not an effective neutralizing agent. For example, 11 kilograms of calcium carbonate elevated the pH of 4,400 kg of lake water from 4.3 to 5.2 while 0.02 kg of calcium hydroxide raised the pH of a similar lake volume from 4.3 to 7.2. For a number of years staff of Falconbridge Nickel Limited have been successfully neutralizing tailing wastes with crushed limestone prior to discharge to Moose Lake. With respect to this operation, chemical as well as biological (at least at the primary and secondary levels) conditions in the water column appear adequate to support a minimum fishery. However, we feel the unconsolidated flocculant material which was noted lying above the lake's natural sediments (in some instances up to 2m in depth) would preclude a healthy environment for establishing a viable bottom faunal base and hence minimize a potential fish-food resource. Nonetheless, and of some encouragement, the neutralization process appears, at least superficially, to be restoring water quality of Moose Lake. Based on the above mentioned documentation, the decision was effected during the late winter of 1973 to assess on a pilot-scale basis, the feasibility of reclaiming lakes affected by inputs of sulphuric acid derived from atmospherically-conveyed sulphur dioxide.

DESCRIPTION OF THE STUDY AREA

Following extensive field surveys conducted in June of 1973, two pairs of lakes were selected, Hannah and Middle and Clearwater and Lohi (Figure 1). Hannah and Clearwater, the upstream lakes of each pair, served as reference or control systems while reclamation efforts were carried out in the two downstream lakes, Middle and Lohi. All lakes drain via the Vermillon River to the Spanish River and ultimately to the North Channel of Lake Huron. In terms of flushing, the lakes are ideally suited to our experimental design, with periods ranging from 1.12 years for Lohi Lake to 3.52 years for Clearwater Lake. The predominating bedrock for each lake consists of Wanapitei quartzite with minor

intrusions of the nickel eruptive formation, indicating lake systems which would be extremely sensitive to slight "acid loadings". The lakes lie in a south - southwest direction from the City of Sudbury and are almost due south of the Copper Cliff smelting complex. Shoreline vegetation for the Hannah-Middle Lake combination is sparse; in contrast, lush 50-20 years stands of poplar and birch characterize the watershed of the Clearwater-Lohi pair. Various morphometric data for the lakes under study are presented in Table 1.

DISCUSSION OF RESULTS¹

Water Clarity

Secchi disc data are summarized in Table 2 while the seasonal variations in light penetration for representative "deep water" stations are presented in Figure 2. As indicated, mean Secchi disc transparencies

¹ A complete description of field and laboratory methodologies as well as philosophies and rationale relating to selection of neutralizing substances can be found in Michalski and Adamski (1974).

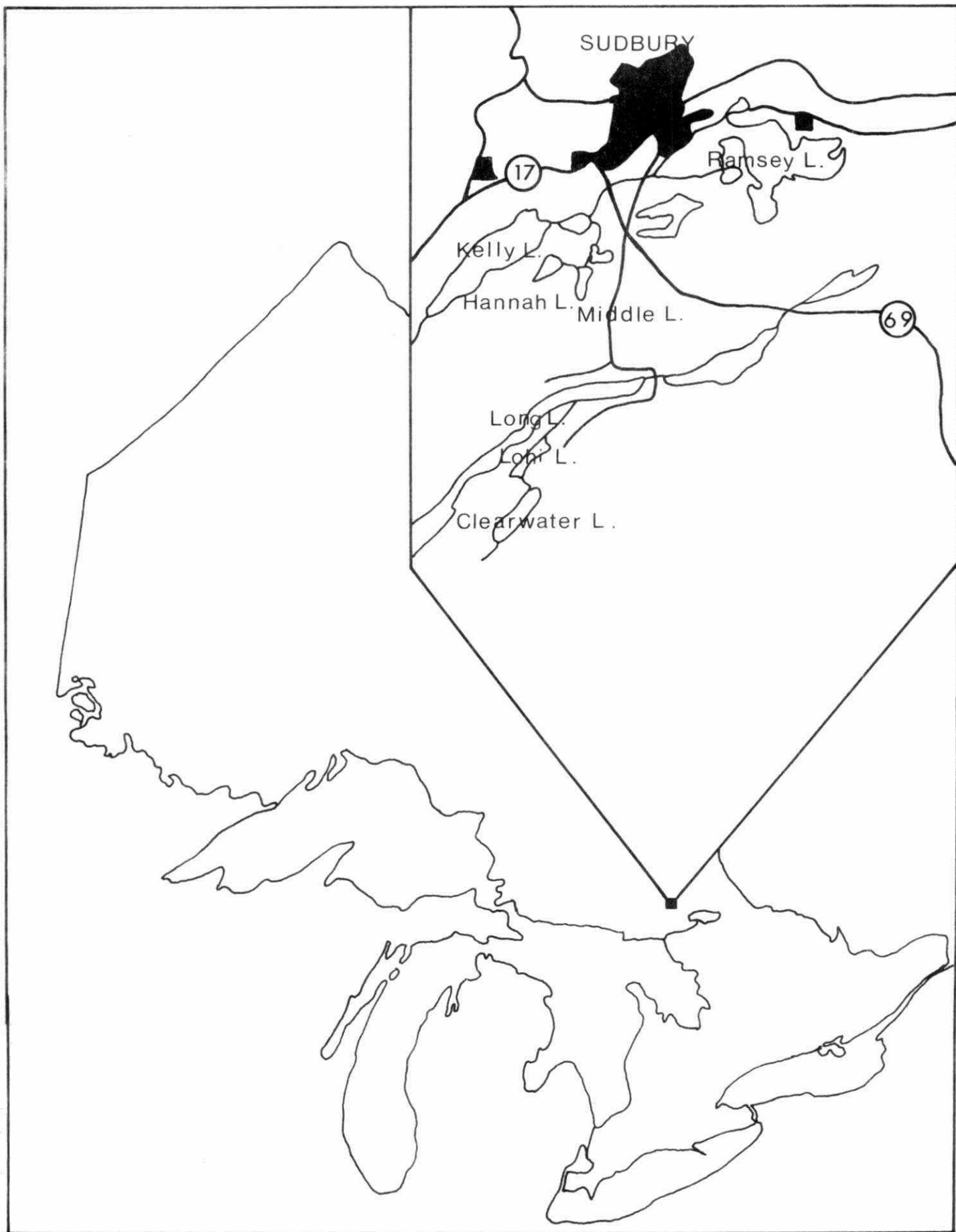


Figure 1: Diagrammatic representation of the reclamation lakes study area.

Table 1: Morphometric data for Lakes Middle, Hannah, Lohi and Clearwater, located in the Sudbury area of Ontario.

	Middle	Hannah	Lohi	Clearwater
Co-ordinates				
Latitude	81° 01' W	81° 02' W	81° 06' W	81° 03' W
Longitude	46° 26' W	46° 26' N	46° 23' N	40° 22' N
Altitude				
(m)	289.6	289.6	282.0	285.0
Maximum Depth, Z				
(m)	13.6	7.5	16.8	18.9
Mean Depth, \bar{Z}				
(m)	9.4	5.9	9.2	8.8
Length of Shoreline, L				
(km)	3.2	2.7	4.2	4.7
Lake Area, A_0				
(ha)	21.1	17.8	29.2	76.8
Lake Volume, V				
($m^3 \times 10^6$)	2.2	1.4	3.1	6.9
Turnover Time, T_w				
(years)	1.36	1.74	1.12	3.50
Approximate Distance from Smelter				
(km)	5	4	10	12

Table 2: Pre-and post-treatment Secchi disc (m), chlorophyll a ($\mu\text{g l}^{-1}$), total phosphorus (as $\mu\text{g l}^{-1}$ P), free ammonia and nitrate nitrogen (as mg l^{-1} N) and molybdate reactive silica (as mg l^{-1} SiO_2) data for Middle and Lohi Lakes. Values represent means of 5-20 data sets except for 1974 information which reflects conditions on one sampling occasion (i.e. January 22). Data for reference Lakes Hannah and Clearwater are also presented.

	Middle Lake			Hannah Lake		Lohi Lake			Clearwater Lake	
	Pre-treatment	Post treatment		1973	1974	Pre-treatment	Post treatment		1973	1974
	1973	1973	1974			1973	1973	1974		
Secchi disc	9.6	12.4		7.5	-	8.9	16.4	-	12.3	-
Chlorophyll <u>a</u>	0.9	0.4	*	0.8	1.6	1.7	0.5	*	1.3	4.5
Total Phosphorus	7	4	4	8	4	8	4	2	6	3
Free Ammonia	.04	.02	.12	.10	.05	.07	.06	.05	.05	.01
Nitrate	.04	.41	.38	.67	.85	.08	.08	.12	.11	.10
Silica	2.8	3.1	3.6	1.1	1.8	2.8	2.6	3.1	4.4	5.3

* interference

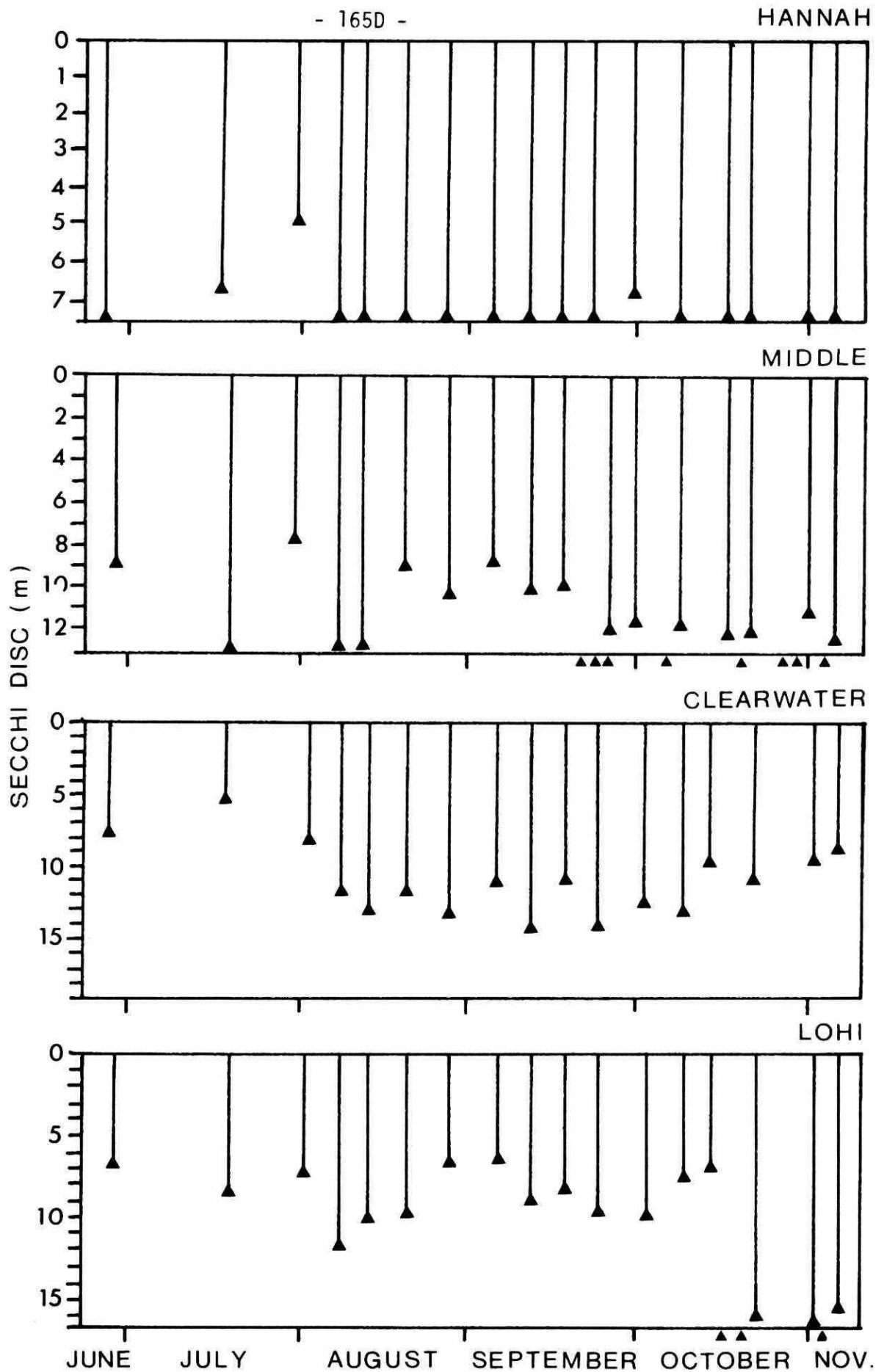


Figure 2: Secchi disc readings (m) at centrally located station in Hannah, Middle, Lohi and Clearwater Lakes, 1973. Occasions of lime additions to Middle and Lohi Lakes are indicated by closed triangles.

varied from 7.5m in Hannah Lake (i.e. the Secchi disc was visible on the lake's sediments) to 12.3m in Clearwater Lake. Such readings are similar to data collected for a number of Ontario's most unproductive Precambrian Shield lakes (i.e. Lake Joseph - 8.1m; Lake Rosseau - 6.2m; Hall's Lake - 7.8m) and clearly reflect the poorly productive nature of systems affected by atmospherically conveyed sulphuric acid. Light penetration increased following treatment with Ca(OH)_2 , suggesting a diminution in the water column's particulate and/or planktonic material - likely a consequence of physical removal via flocculation and precipitation.

Temperature and Dissolved Oxygen Conditions

In general, all lakes were near-homothermous during the 1973 summer season (Figure 3), with surface waters as high as 24°C (Lakes Hannah, Middle and Clearwater). It is somewhat surprising that a strong, long-lasting metalimnion did not develop in the lakes, especially in the deeper Lakes Clearwater and Lohi. However, based on our early spring 1974 data, it is suggested that a brief period of stratification likely materialized prior to our routine sampling in 1973.

Oxygen distributions were orthograde or non-diminishing with depth for all lakes, although deficits were occasionally detected in the near-bottom waters of Lohi Lake (Figure 4). These orthograde distributions indicate low levels of biological activity within the lakes.

pH, Hardness, Alkalinity and Conductivity

In normal lake water, the greatest percentage of the total ionic content is expressed as a balance between the positive calcium and magnesium (hardness) and negative biocarbonate and carbonate ions (alkalinity). A smaller percentage of the ionic content consists of the balance between the positive sodium and potassium and negative chloride, sulphate and nitrate ions. An excess of calcium is desirable since it has the capability of fixing and converting atmospheric CO_2 to bicarbonate ions. The pH then, is established on the basis of the extent of bicarbonate availability. However, the study lakes are somewhat atypical in that sulphate is the largest single ionic constituent and the greatest percentage of the total ionic content is a balance between the positively charged calcium and magnesium ions on the one hand and negatively charged sulphate ions on the other. The unusually high sulphate levels contribute to deficiencies in reactive calcium which precludes the establishment of a bicarbonate buffer

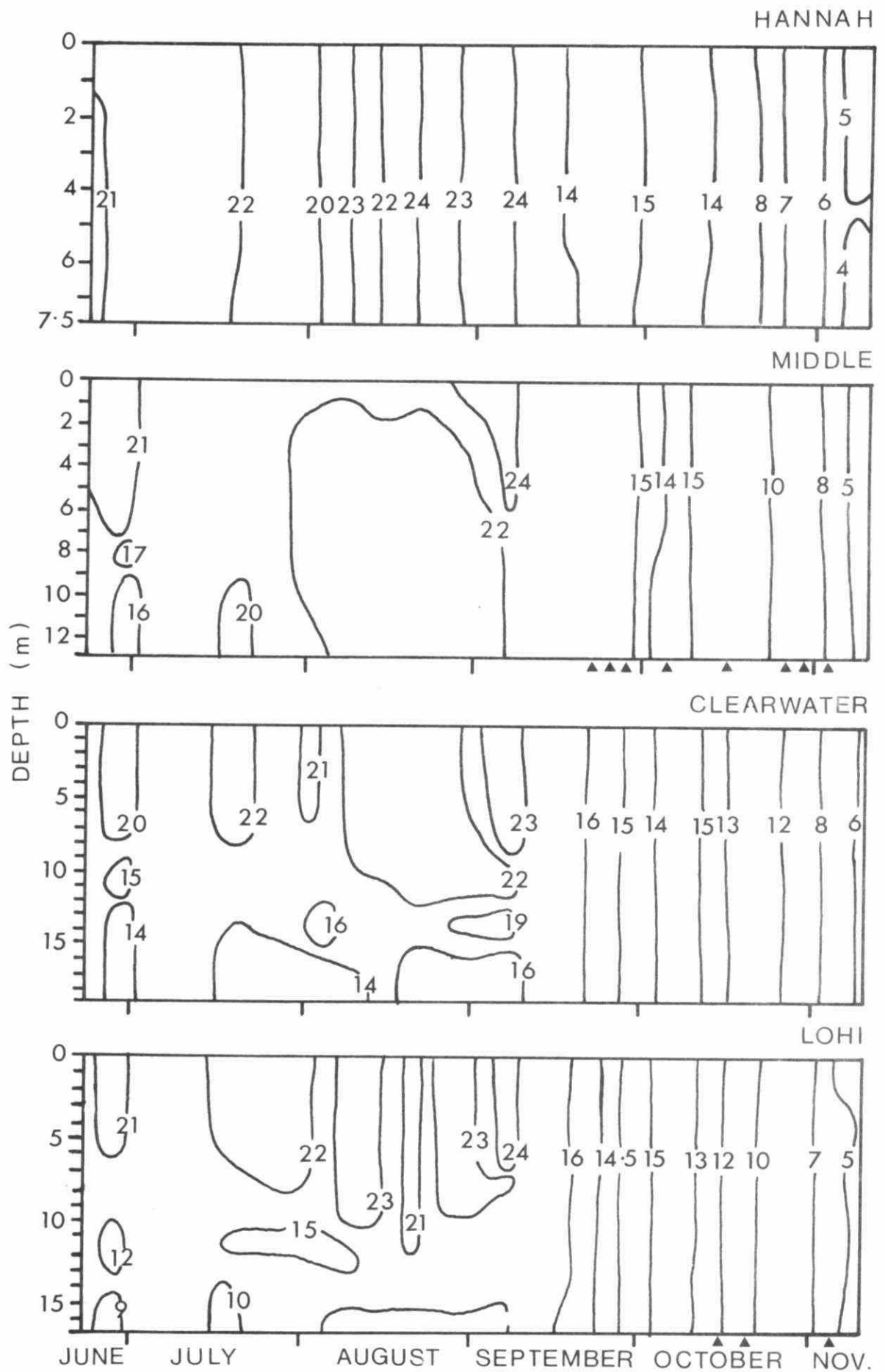


Figure 3: Seasonal isotherms ($^{\circ}\text{C}$) at deep-water stations in Hannah, Middle, Clearwater and Lohi Lakes, 1973. Occasions of lime additions to Middle and Lohi Lakes are indicated by closed triangles.

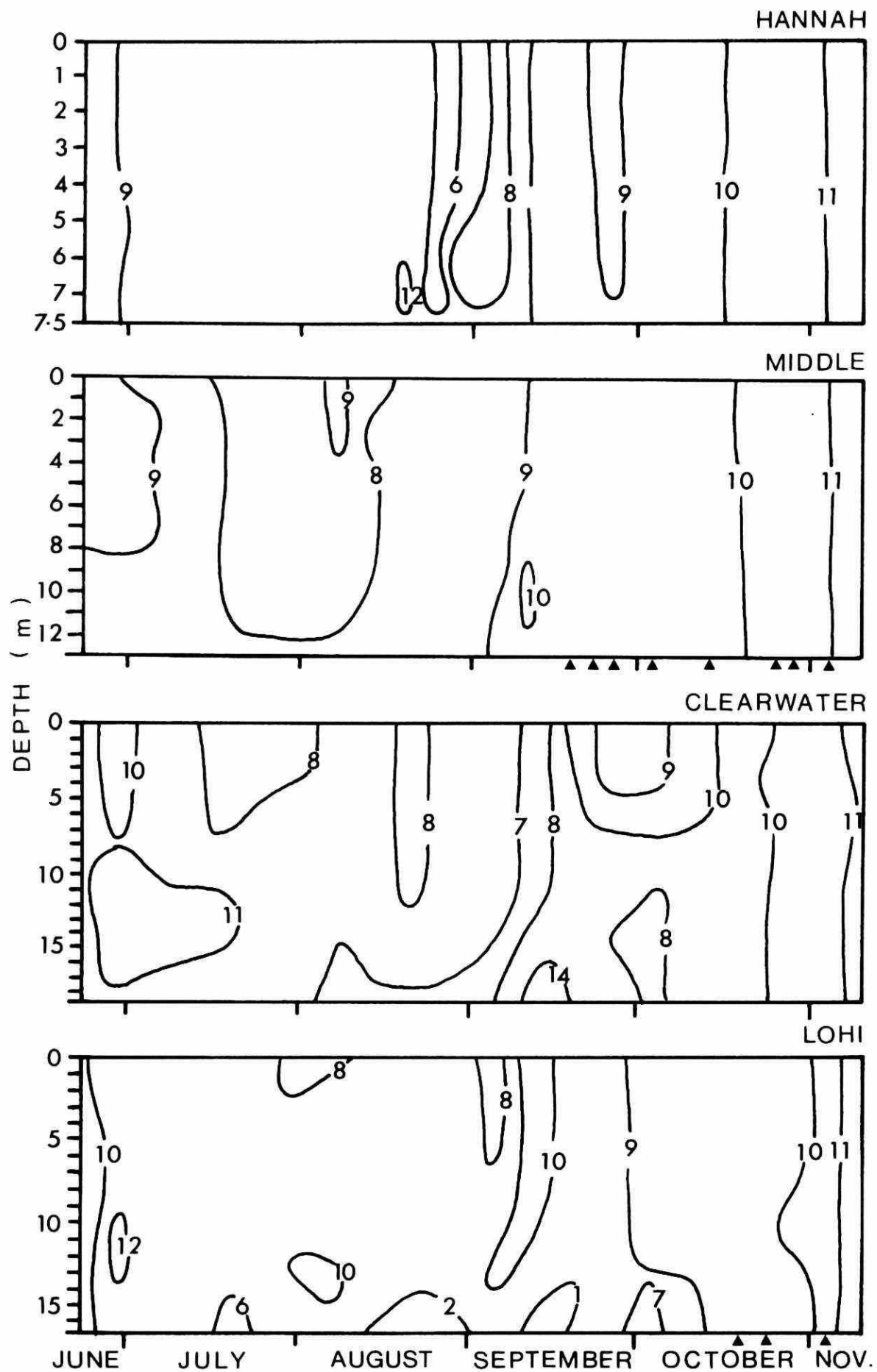


Figure 4: Seasonal isopleths of dissolved oxygen (mg l^{-1}) at deep-water stations in Hannah, Middle, Clearwater and Lohi Lakes, 1973. Occasions of lime additions are indicated by closed triangles.

system. As indicated in Table 4, bicarbonate ions were not detected in the study lakes prior to neutralization operations. The negligible quantity of bicarbonate ions noted in the lakes prior to treatment is characteristic of a poorly buffered system and one whose natural ability to maintain an acceptable pH is minimal. In summary, the low pre-treatment pH levels are a result of the abnormal mineral balance, which is attributable to a combination of the natural calcium deficiency in Precambrian Shield lakes and artificial inputs of excess sulphate ions via local industrial operations.

Predictably, following our reclamation efforts (a summary of chemical quantities and scheduling is provided in Table 3), elevated pH levels to the near-neutral range occurred and were maintained, for the most part, throughout the winter and into the spring months of 1974 (Figure 5). Similarly, increases in hardness and calcium occurred (Table 4). Concomitant with the foregoing was the establishment of a normal buffer system with alkalinity increasing from 0.0 to 9.0 mg l⁻¹ in Middle Lake and from 0.0 to 4.5 mg l⁻¹ in Lohi Lake. Under the ice and early spring alkalinity concentrations continued to increase in Middle Lake but decreased slightly in Lohi Lake (see Table 4), reflecting the impact of CaCO₃ additions to the former system. As pointed out earlier, CaCO₃ is less reactive than Ca(OH)₂; however, this chemical appears to provide a more longer-lasting neutralizing effect by injecting a continuous residual buffer to the lake. Indeed, CaCO₃ may prove to be especially useful as a neutralizing agent once the initial pH adjustment has been effected.

The decreases in conductivity following treatment, although initially surprising, were predicted on the basis of the ionic composition of the lake water (see Table 4). Specifically, changes in the hydrogen and calcium ion content were responsible for these decreases. As pointed out above, pre-treatment conditions indicated a major conductivity contribution owing to hydrogen ions which were gradually eliminated with the pH increase. However, the contribution of calcium to augmenting the lakes conductivity was not sufficient to compensate for hydrogen ion losses.

TABLE 3: Schedule of application of neutralization chemicals to Middle and Lohi Lakes, 1973.

DATE	CHEMICAL APPLIED	DOSAGE APPLIED kg (tons)	
		Middle Lake	Lohi Lake
25/9/73	Ca(OH)_2	2,721 (3)	- -
26/9/73	Ca(OH)_2	5,442 (6)	- -
28/9/73	Ca(OH)_2	907 (1)	- -
3/10/73	Ca(OH)_2	7,256 (8)	- -
16/10/73	Ca(OH)_2	- -	9,070 (10)
17/10/73	Ca(OH)_2	1,814 (2)	4,535 (5)
29/10/73	Ca(OH)_2	1,814 (2)	- -
31/10/73	CaCO_3^1	7,256 (8)	- -
1/11/73	CaCO_3	6,349 (7)	- -
2/11/73	Ca(OH)_2	- -	4,535 (5)
	Ca(OH)_2	19,954 (22)	18,140 (20)
	CaCO_3	13,605 (15)	- -

¹ Calcium carbonate is considered to be an extremely slow reacting neutralizing substance; however, we were interested in assessing its potential in terms of affording a residual or long-lasing buffer to the lake once the initial pH adjustment was effected.

Table 4: Pre-and post-treatment pH, alkalinity (as $\text{mg l}^{-1} \text{CaCO}_3$), hardness (as $\text{mg l}^{-1} \text{CaCO}_3$), calcium (as mg l^{-1}), sodium (as mg l^{-1}), potassium (as mg l^{-1}), sulphate (as mg l^{-1}), conductivity (as $\mu\text{mhos cm}^{-2}$) and free CO_2 (as mg l^{-1}) data for Middle and Lohi Lakes. Values represent means of 5-20 data sets except for 1974 information which reflects conditions on one sampling occasion (i.e. January 22). Data for reference Lakes Hannah and Clearwater are also presented.

	Middle Lake			Hannah Lake		Lohi Lake			Clearwater Lake	
	Pre-treatment 1973	Post treatment 1973	1974	1973	1974	Pre-treatment 1973	Post treatment 1973	1974	1973	1974
pH	4.5	7.6	7.3	4.4	4.6	4.4	7.0	6.1	4.4	4.4
Alkalinity	0.0	9.0	10	0	0	0	4.5	3	0	0
Hardness	39	52	57	46	50	21	29	31	21	22
Conductivity	135	125	147	168	185	87	76	85	91	94
Calcium	10	16	18	12	13	6	9	10	6	6
Magnesium	4	3	3	3	3	2	1	2	2	1
Sodium	2	2	2	3	3	2	2	1	2	1
Potassium	2	1.6	1.8	2.0	2.1	1.3	1.3	1.4	1.3	1.3
Sulphate	45	45	47	56	67	27	27	28	28	29
Free CO_2 ez ¹	8.3	0	1.9	11	13.5	5.9	4.3	2.3	6.3	6.2
bt ²	7.7	0	6.5	12	14.2	14.0	4.3	3.1	6.3	7.7

¹ euphotic zone

² bottom

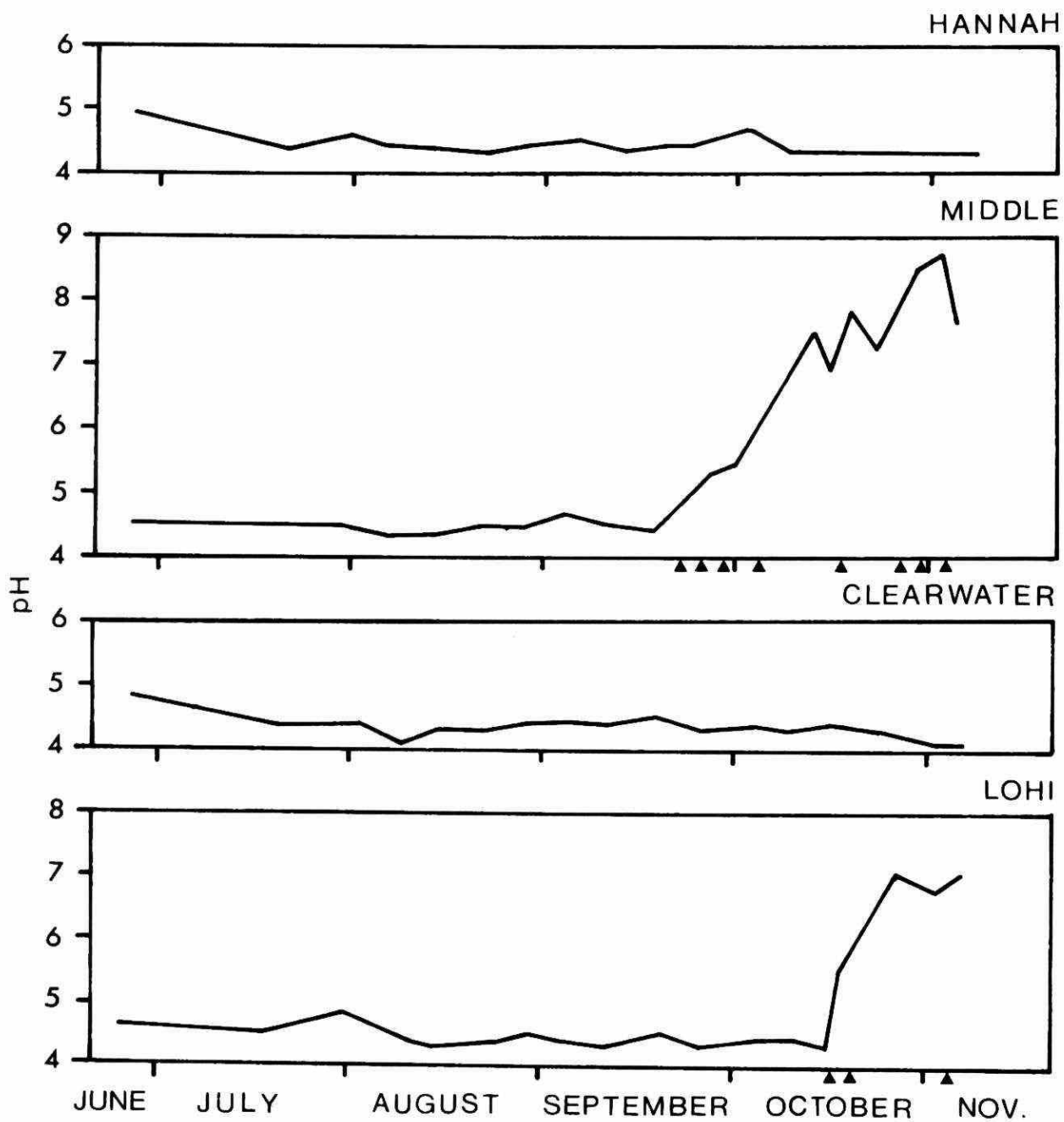


Figure 5: pH conditions at centrally-located stations in Hannah, Middle, Clearwater and Lohi Lakes, 1973. All data are based on samples secured from a depth of 1m. Occasions of lime additions to Middle and Lohi Lakes are indicated by closed triangles.

Table 6: Chemical composition of top and bottom portion sediment core sections taken from Middle and Lohi Lakes, 1973.
Also, similar data from Harp Lake in the Muskoka Lakes area of the Province are provided for comparative purposes.

Parameter	Middle Lake		Lohi Lake		Harp Lake
	Top Section of Core	Bottom Section of core	Top Section of Core	Bottom Section of Core	Averages
Pretreatment pH	5.5	6.2	5.5	6.0	-
Loss on Ignition (%)	22.	25.	16.	17.	27.
Total Nitrogen (mg g^{-1})	7.0	7.7	5.5	5.8	9.3
Total Phosphorus (mg g^{-1})	1.3	1.4	1.1	1.2	2.3
Chromium ($\mu\text{g g}^{-1}$)	65.7	60.7	56.2	59.7	-
Zinc ($\mu\text{g g}^{-1}$)	145	130	127	107	153
Copper ($\mu\text{g g}^{-1}$)	1140	226	448	116	35.9
Nickel ($\mu\text{g g}^{-1}$)	1710	334	563	145	<5.0
Manganese ($\mu\text{g g}^{-1}$)	261	382	235	329	897
Iron (%)	3.84	2.15	2.33	2.00	2.57
Calcium ($\mu\text{g g}^{-1}$)	2120	2230	1720	2570	5500
Magnesium ($\mu\text{g g}^{-1}$)	3130	3190	4120	5130	3530

Lake Sediments

An overall characterization of sediment chemistry is of importance in clarifying lake behaviour with a view to offering predictions which might be expected on the basis of sediment response and sediment-water interactions during chemical treatment. For example, lake water chemistry may be significantly altered if normally insoluble sediment material is released in a soluble fraction to the overlying water column. Pre-treatment sediment samples were secured as cores from twenty-one stations on Middle Lake and twenty-six stations on Lohi Lake; each core was divided into a top and bottom portion and analyzed separately. Analyses were directed to documenting the composition of the sediments and to providing insights relative to potential chemical release implications. Data on composition of the lake sediments are provided in Table 6; also, information from Harp Lake - an oligotrophic system in the Muskoka Lakes area of the Province - is presented for comparative purposes. The following significant observations were noted:

1. The copper and nickel levels in Lakes Middle and Lohi are appreciably higher than Harp Lake concentrations, suggesting that local industry is the likely metal input source.
2. Copper and nickel concentrations are approximately four to five times higher in the top portion of each core than in the bottom section indicating a recent deposition process, and again implying that smelter emissions are the likely heavy metal source.
3. Similar relative amounts of zinc were noted for Middle, Lohi and Harp Lakes. Since air quality data indicate that zinc is a negligible component of local smelter emissions, the results are predictable.
4. There appears to be an atypical relationship between calcium and magnesium in the sediments of Middle and Lohi Lakes. Under normal conditions, lake sediment calcium concentrations are approximately 1.5 to 3 times higher than magnesium levels. For example, Harp Lake fits the expected ratio; however, in Middle and Lohi Lakes, magnesium levels exceed by a factor of two calcium concentrations. A logical explanation for this observation is not available.

Table 5: Pre-and post-treatment data (mg/l) for nickel, zinc, copper, iron and manganese in Middle and Lohi Lakes 1973. Similar information for reference Lakes Hannah and Clearwater is also presented. All data are means of samples collected at 1m above sediments.

	*			*		
	Middle Lake		Hannah Lake	Lohi Lake		Clearwater Lake
	<u>Pre-treatment</u>	<u>Post-treatment</u>	<u>1973</u>	<u>Pre-treatment</u>	<u>Post-treatment</u>	<u>1973</u>
	1973	1973		1973	1973	
Nickel	1.05	0.19	1.60	0.25	0.12	0.38
Zinc	0.090	0.012	0.12	0.070	0.019	0.05
Copper	0.48	0.032	1.10	0.080	0.011	0.14
Iron	0.11	0.23	0.07	0.42	0.008	0.11
Manganese	0.35	0.14	0.40	0.28	0.21	0.32

Heavy Metals

Soluble heavy metals, primarily copper and nickel were excessive in all four experimental lakes (Table 5), likely originating from local industrial operations since a good relationship has been demonstrated between lake water metal concentrations and distance from the smelting complex (Gorham and Gorham 1960, Gorham and Gorham 1963 and Conroy 1971). Air quality data, which includes precipitation monitoring, further confirms the metal origin (Conroy 1971 and McGovern and Balsillie 1973). As indicated in Table 5, the highest heavy metal concentrations were found in Hannah Lake, which is the closest of our four experimental lakes to the smelter (i.e. 4km). Middle Lake, only 1km farther south from the industrial complex than Hannah Lake, is characterized by substantially lower heavy metals than Hannah Lake. Lohi and Clearwater Lakes are some 10-12km from the smelter and contain substantially lower levels of heavy metals than the more northern lake-pair. Of all metals measured, copper is of major concern from a toxicological point of view. Mount and Stephan (1969) pointed out that chronic long-term effects owing to copper toxicity can be expected between 10 and 20 $\mu\text{g l}^{-1}$ in soft-water systems. If one assumes the worst (i.e. all copper is present as the free metal ion), the limit established by Mount and Stephan (1969) would be exceeded in each of the four experimental lakes. However, it is unlikely that all copper is available in the free ionic state. In 1973 Ministry of the Environment analytical procedures did not distinguish between the various metallic forms. As indicated in Table 5, reductions in soluble heavy metals occurred following neutralization. For example, Middle Lake was characterized by an 82% reduction in nickel, a 97% reduction in copper an 87% reduction in zinc and a 61% reduction in manganese. Similar reductions for Lohi Lake were noted: nickel 52%; copper 86%; zinc 73% and manganese 25%. Concentrations of the aforementioned heavy metals captured in sediment traps located at depths approximating 1m above bottom following neutralization suggested a precipitation mechanism. The reduction of copper is considered to be most significant since, as mentioned above, pre-treatment levels of this element exceeded the accepted limits for fish toxicity in soft-water lakes. Toxicity effects owing to excessive levels of copper are presently considered to be negligible and the probability of establishing and maintaining a fishery appears quite good (other factors being equal).

5. Loss on ignition, total phosphorus and total nitrogen are consistently higher for Middle than Lohi Lake sediments. Considering that shoreline vegetation is far more extensive for Lohi, this relationship is difficult to explain.
6. Based on laboratory experimentation, significant elevations in nutrients, especially phosphorus and free ammonia, were anticipated. However, such releases did not materialize. Extensive mixing provided during the laboratory procedures likely influenced the degree and rate of release. Such mixing does not occur under natural conditions; consequently, significant releases of soluble material to overlying waters should only materialize over a long-term basis (other factors being equal).

Nutrients

The seasonal pattern for total phosphorus in the euphotic zone and at 1m above bottom for the lakes under study are presented in Figure 6; absolute pre- and post-treatment differences in nitrate and free ammonia nitrogen, orthosilica as well as total phosphorus are displayed in Table 2. As indicated, total phosphorus levels were exceptionally low and tended to be somewhat variable throughout the summer sampling season. Following treatment, concentrations were slightly depressed in relation to pre-treatment levels. Only minor variations in ammonia nitrogen and ortho-silica were noted following treatment while slight nitrate nitrogen increases resulted. The exceptionally low phosphorus levels are indicative of ultra-oligotrophic systems. An examination of Table 7 which presents information in terms of N/P indicates how phosphorus can be "made to be limiting" to reduce conditions of accelerated eutrophy by implementing various management techniques (i.e. Lake Washington¹ and Gravenhurst Bay). Lakes Hannah, Middle, Clearwater and Lohi with N/P ratios of 115.1, 67.0, 31.9 and 44.5, respectively are clearly phosphorus limited. It is suggested that the establishment of adequate primary and secondary levels as support to a fisheries may require stimulation through nutrient additions - particularly phosphorus.

¹ reproduced from Edmondson, 1970.

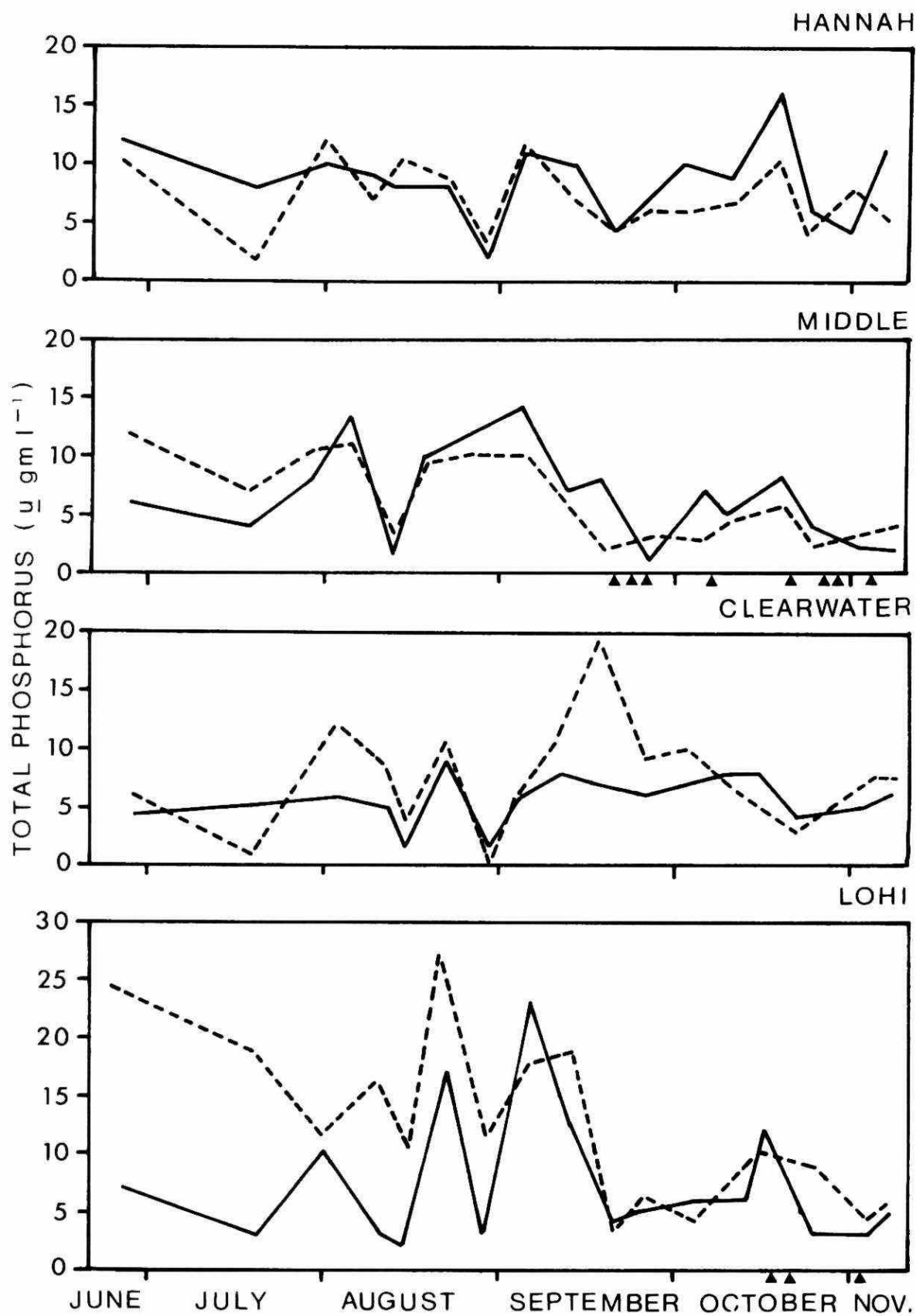


Figure 6: The seasonal patterns for total phosphorus ($\mu\text{g l}^{-1}$) in the euphotic zone (solid lines) and at 1m above bottom (broken lines) in Hannah, Middle, Clearwater and Lohi Lakes, 1973. Occasions of lime additions to Middle and Lohi Lakes are indicated by closed triangles.

Table 7: Nitrogen to phosphorus ratios are presented for Lake Washington and Gravenhurst Bay prior to and following management programmes to reverse conditions of accelerated eutrophication. Similar ratios are presented for Lakes Hannah, Middle, Clearwater and Lohi in the Sudbury area.

Lake	Year	N/P
Washington	1933	50
Washington ¹	1962	10
Washington ²	1967	15
Washington ²	1969	20
Gravenhurst Bay ¹	1969	11.2
Gravenhurst Bay ¹	1970	11.9
Gravenhurst Bay ²	1971	15.2
Gravenhurst Bay ²	1972	18.9
Gravenhurst Bay ²	1973	17.5
Hannah Lake	1973	115.1
Middle Lake ³	1973	67.0
Middle Lake ⁴	1973	289.1
Clearwater Lake	1973	31.9
Lohi Lake ³	1973	44.5
Lohi Lake ⁴	1973	35.9

¹. N/P ratios prior to sewage diversion for Lake Washington. Construction started in 1963 and ended in 1967; by the middle of 1965, about one half the effluent had been diverted. In the case of Gravenhurst Bay, reductions of in excess of 80% of the phosphorus loadings from the Gravenhurst and Ontario Hospital Sewage Treatment Plants to the Bay were effected.

². N/P ratios following management practices to reduce phosphorus loadings.

³. N/P ratios prior to neutralization activities.

⁴. N/P ratios following reclamation with Ca(OH)_2 and/or CaCO_3 .

Chlorophyll a and Phytoplankton Stocks

An indication of the seasonal patterns in chlorophyll a concentrations is presented in Figure 7, while the maximum, minimum and mean values for each lake are summarized in Table 2. As illustrated, plant pigment concentrations were very low for all four lakes. For example, a maximum chlorophyll a value of $3.9 \mu\text{g l}^{-1}$ was recorded on August 21, 1973 in Lohi Lake; usually concentrations rarely exceeded $1.0 \mu\text{g l}^{-1}$, again reflecting the unproductive nature of the lakes.

The seasonal pattern in phytoplankton development (in a.s.u. ml^{-1}) and successional changes for the major taxonomic classifications (expressed as percent composition) are presented in Figure 8. Clearly defined patterns in phytoplankton development did not materialize during the sampling period; however, the development of spring algal pulses cannot be overlooked at this point. Analyses of samples collected in April, May and June of the current year (i.e. 1974) will be helpful in confirming growth patterns in the lakes. Phytoplankton stocks prior to neutralization averaged 187, 134, 144 and $246 \text{ a.s.u. ml}^{-1}$ for Lakes Hannah, Middle, Clearwater and Lohi, respectively; such levels are considered to be extremely low in magnitude. Table 8 provides, for comparative purposes, a breakdown of phytoplankton conditions for several lakes in Ontario. The data are based on collections approximating the same ice-free period when samplings were obtained for the study lakes (although years are different). Significantly, the experimental lakes are less productive than a number of Ontario's most oligotrophic lake systems (i.e. Lakes Joseph and Rosseau, Georgian Bay and Little Otter Lake, 1972). The most important algal types included unconfirmed (or possibly unknown) species of Chlorophyceae (Mougeotia, Oocystis and Selenastrum), Dinophyceae (Peridinium) and Chrysophyceae (Dinobryon) and Cryptophyceae (Cryptomonas and Rhodomonas). Representatives of the Bacillariophyceae (diatoms) and Myxophyceae (blue-greens), forms typical to the mid-summer flora of most Precambrian lake systems having near-neutral pH, were conspicuously absent.

Immediate decreases in both chlorophyll a and phytoplankton biomass were evident following neutralization, probably as a consequence of precipitation through floc formation (see Figures 7 and 8 and Table 8). Such decreases corresponded completely with the earlier mentioned improvements in lake water clarity conditions resulted from sedimented particulate organic and/or inorganic fractions. We anticipate that some increases at

both the primary and secondary levels of production will materialize in future years as long as near-neutral pH conditions are maintained. In this regard, efforts in subsequent seasons will be directed in a step by step fashion towards establishing a stable food chain prior to introducing forage and game fish species.

GENERAL COMMENTS

With a view to the study area, it is important to recognize that the acidic lakes (i.e. prior to treatment) are abnormal, unnatural and, in essence, polluted and require corrective actions. Chemical manipulation of depressed pH lake-types to near-neutral status results in clearly defined improvements to the lakes' chemistry through the replenishment of a calcium deficiency. Once this deficit has been satisfied, a normal and natural mineral balance will develop to enhance recovery of the lakes. Initial results from our 1973 field experiments have shown that $\text{Ca(OH)}_2/\text{CaCO}_3$ treatment is an attractive, simple, effective and relatively inexpensive "water management tool" for reclaiming acidic lakes. Reflectively and relative to our overall goals of establishing and maintaining a viable fisheries resource, we are, at this stage, cautiously optimistic.

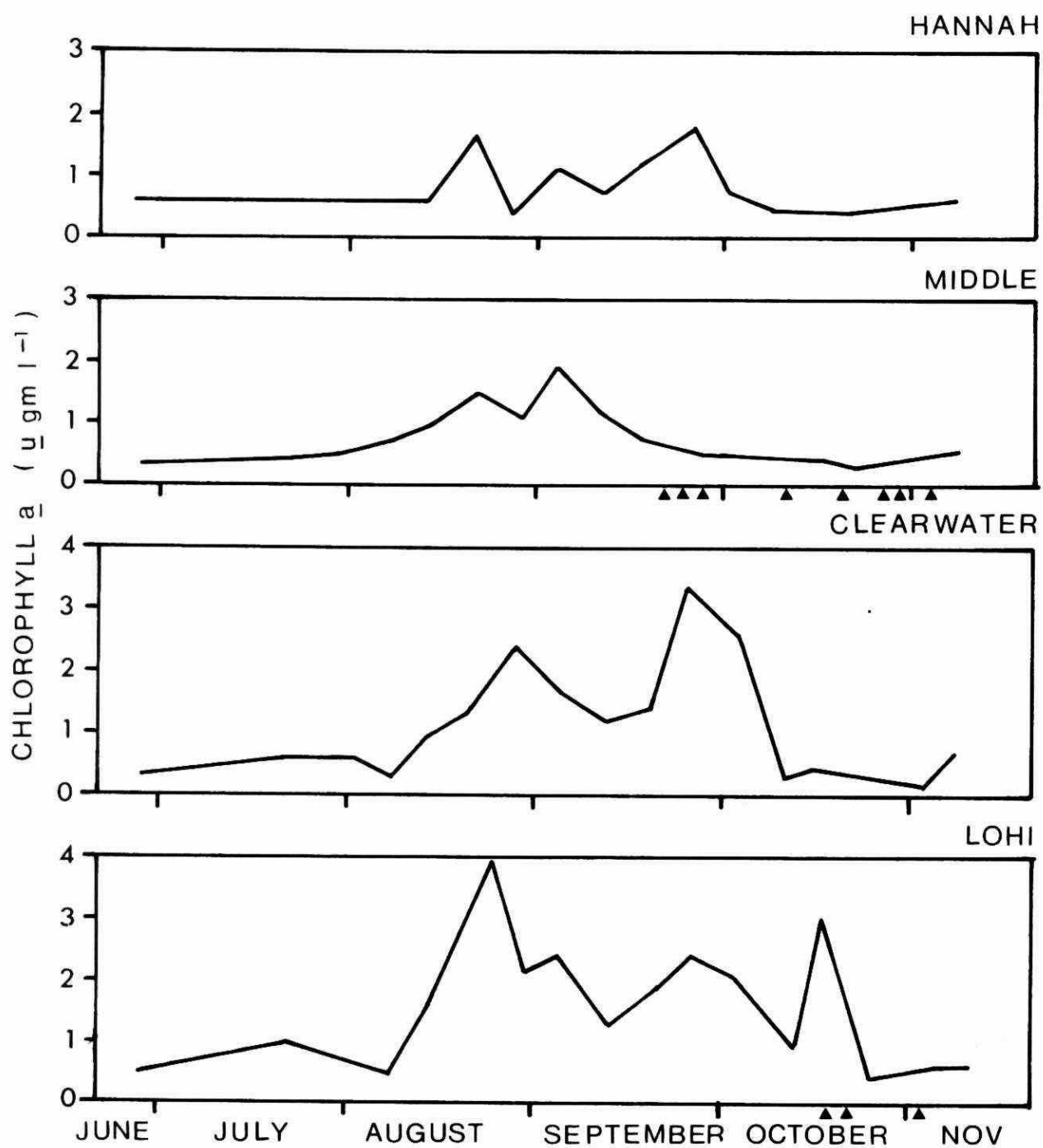


Figure 7: Seasonal trends in chlorophyll a ($\mu\text{g l}^{-1}$) in the euphotic zones of Hannah, Middle, Clearwater and Lohi Lakes, 1973. Occasions of lime additions to Middle and Lohi Lakes are indicated by closed triangles.

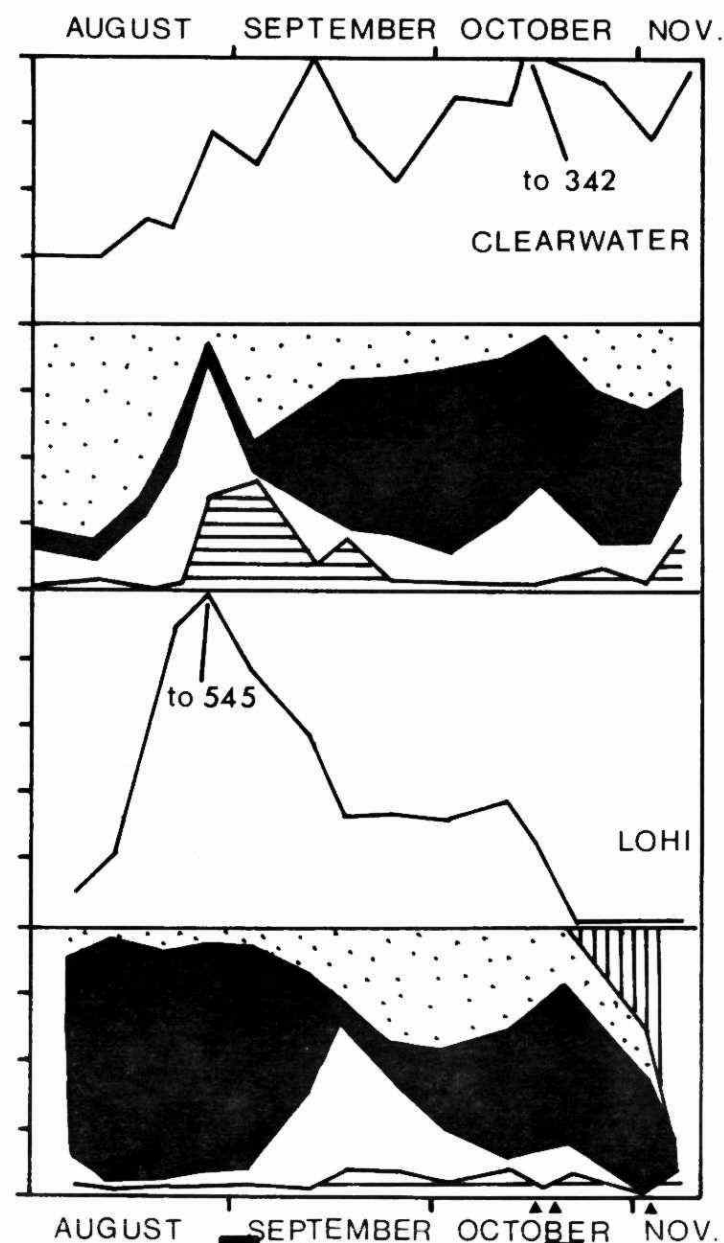
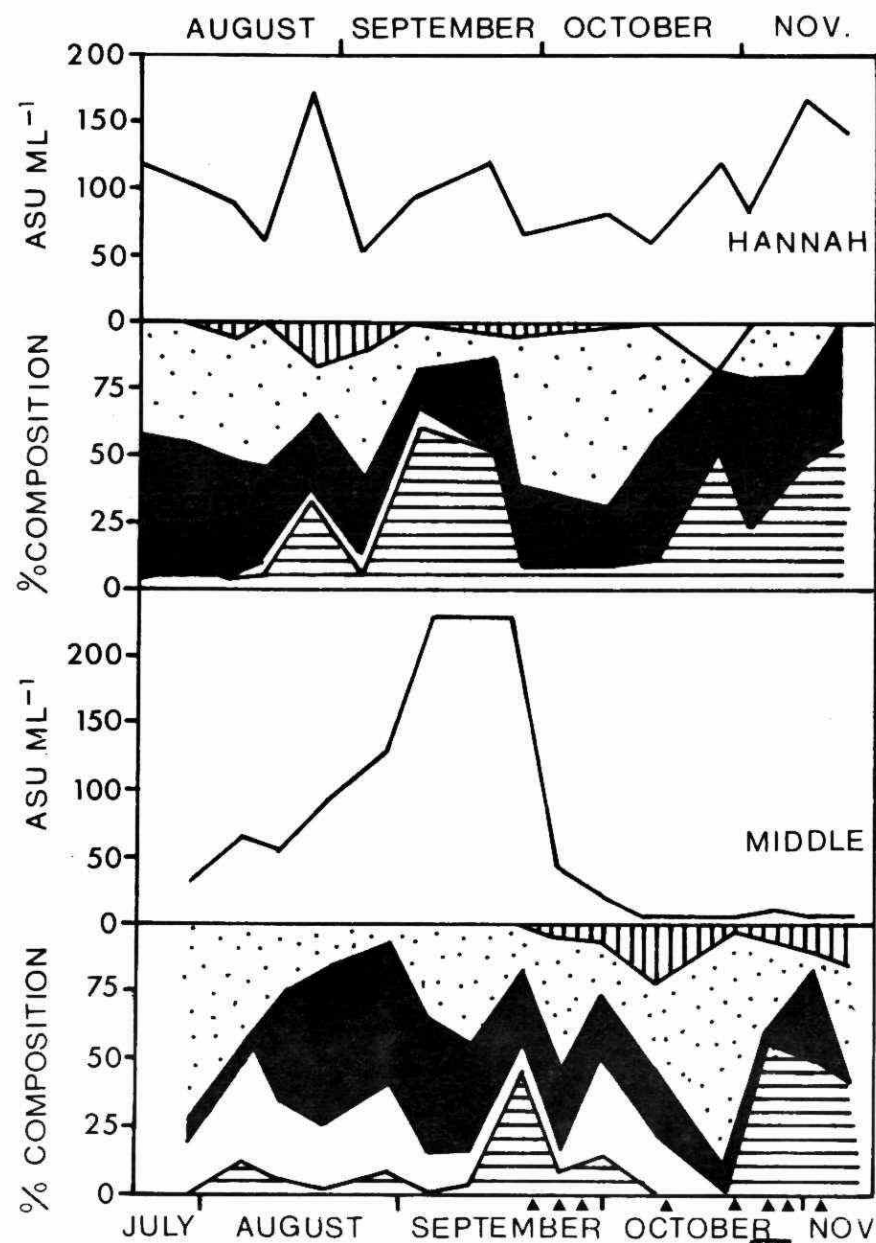
Figure 8: Phytoplankton stocks (a.s.u. ml⁻¹) composition (%) in the euphotic zones of Hannah, Middle, Lohi and Clearwater Lakes, 1973. Occasions of lime additions to Middle and Lohi Lakes are indicated by closed triangles.

Table 8: Summary of phytoplanktonic data collected from the euphotic zones of Lakes Hannah, Middle, Clearwater and Lohi, 1973. Data from other lakes in the Province are presented for comparative purposes. All results are expressed as areal standard units ml^{-1} .

Municipality	Source	Year	Number of Samples	Areal Standard Units ml^{-1}		Status
				Range	Mean	
-	Lake Joseph	1969	21	31 - 1,153	402	Oligotrophic
-	Lake Rosseau	1969	22	54 - 1,880	479	Oligotrophic
Collingwood	Georgian Bay	1968	207	7 - 708	226	Oligotrophic
Kingsville	Lake Erie, Western Basin	1969	26	1,022 - 7,147	3,190	Eutrophic
Gravenhurst	Gravenhurst Bay	1969	25	134 - 6,402	2,686	Eutrophic
-	Little Otter Lake	1971*	9	667 - 19,387	5,175	Eutrophic
-	Little Otter Lake	1972**	63	84 - 1,114	400	Oligotrophic
Sudbury	Hannah Lake	1973	15	49 - 179	107	Acidified
Sudbury	(a) Middle Lake	1973	8	32 - 232	134	Acidified
Sudbury	(b) Middle Lake	1973	7	1 - 46	13	Following neutralization
Sudbury	Clearwater Lake	1973	15	54 - 342	144	Acidified
Sudbury	(a) Lohi Lake	1973	11	52 - 545	246	Acidified
Sudbury	(b) Lohi Lake	1973	3	5 - 13	9	Following neutralization

* Little Otter Lake during high artificial loadings of a polyphosphate de-scaling agent.

** Little Otter Lake following elimination of the polyphosphate discharge.



MIDDLE

LOHI

Bacillariophyceae

Chlorophyceae

Dinophyceae

Chrysophyceae

Cryptophyceae

REFERENCES

- BALL, R.C. 1948. A summary of experiments in Michigan lakes on the elimination of fish populations with rotenone, 1934 - 1942. Trans. Am. Fish. Soc., Vol. 75, pp. 139-146-
- BOWLING, M.L. and R.L. Busbee. 1964. A three-year study on the effects of lime applications on the standing crops of benthic organisms in Georgia farm ponds. Proc. S.E. Assn. Game and Fish Commissions, 18: 280 - 302.
- CONROY, N. 1971. Classification of Precambrian Shield lakes based on factors controlling biological activity. M.Sc. Thesis, McMaster University, Hamilton, Ontario. 142 p.
- EDMONDSON, W.T. 1970. Phosphorus, nitrogen and algae in Lake Washington after diversion of sewage. Science 169: 690 - 691.
- GORHAM, E. and A.G. Gordon. 1960. The influence of smelter fumes upon the chemical composition of lake waters near Sudbury, Ontario and upon their surrounding vegetation. Canadian Journal of Botany; 38: 477 - 487.
- . 1963. Some effects of smelter pollution upon aquatic vegetation near Sudbury, Ontario. Canadian Journal of Botany; 41: 371 - 378.
- HASLER, D.H., O.M. Brynildson and W.T. Helm. 1951. Improving conditions for fish in brown-water bog lakes by alkalization. Journal of Wildlife Management, Vol. 15, No. 4: 347 - 352.
- MCGOVERN, P.C. and P. Balsille. 1973. Sulphur dioxide (1972) - Heavy metals (1971) levels and vegetative effects in the Sudbury area. Ontario Ministry of the Environment, Air Management Branch Report.
- MICHALSKI, M.F.P. and N. Conroy. 1973. The "Oligotrophication" of Little Otter Lake, Parry Sound District. Proc. 16th Conference Great Lakes Research. International Association of Great Lakes Research. 934 - 948.
- MICHALSKI, M.F.P. and J. Adamski. 1974. Sudbury Environmental Study - Lake Reclamation, Limnological Aspects (in preparation).
- MOUNT, D.I. and E.E. Stephan. 1969. Chronic toxicity of copper to the Fathead Minnow (*Pimephales promelas*) in soft-water. J.Fish. Res. Board of Canada, Vol. 26. No. 9: 2449 - 2457.
- MOYLE, J.B. 1949. Some indices of lake productivity. Trans. Am. Fish. Soc. Vol. 76 (1946): 322 - 334.
- NESS, J.C. 1949. Development and Status of Pond Fertilization in Central Europe. Trans. Am. Fish. Soc., 76: 335 - 358.

- THOMASTON, W.W. and H.D. Zeller. 1961. Results of a six year investigation of soil and water analysis and lime treatments in Georgia farm ponds. Proc. S.E. Assoc. Game and Fish Commission. 15: 236 - 244.
- WATERS, T.F. 1956. The effects of lime application to acid bog lakes in Northern Michigan. Trans. Am. Fish. Soc. Vol. 86: 329 - 344.



CHAIRMAN - SESSION 5

Mr. R. G. Mondoux
Marketing Manager, Eimco Division
Envirotech Canada Limited
Toronto, Ont.

R. G. Mondoux

"An Economic and Environmental
Model for Planning and Forecasting"

BY

Dr. P. A. Victor
Senior Economist
Environmental Approvals Branch
Ministry of the Environment
Toronto, Ontario.



Dr. P. A. Victor

It has long been recognised that economic growth has important environmental implications for the region in which it occurs. A substantial part of the environmental impact of economic activity can be traced to the withdrawal of raw materials from the environment and the discharge of industrial, agricultural and domestic effluents onto the land and into the air and water bodies within the region concerned.

It often happens that these material inputs and discharges do not pose serious environmental problems until they surpass some critical order of magnitude. When this does occur, however, and environmental controls are called for, there may be insufficient time for the careful consideration of alternative policies. Furthermore, some potentially effective policies may well be ruled out as unfeasible because of the social and political considerations that inevitably constrain the rapid formulation of policy.

Another reason why the design and implementation of environmental policies is complicated is that, with increasing knowledge of the environment, some things which were not previously regarded as dangerous are subsequently considered to be worthy of control. In addition to this, there is the public's growing awareness of environmental problems and the increasing value people attach to the broader aspects of environmental quality, as their other needs are met.

Underlying many of these factors is the evolution and growth of the economy. Economic growth is directly related to the production of industrial wastes or residuals and to the use of material inputs from the environment. However, the precise relationship between the output of goods for sale and the output of waste materials for discharge into the environment and the input of materials from the environment is far from clear. Those who call for an end to economic growth perceive some sort of connection between these factors, but economic growth can reflect vastly different rates and patterns of economic change, each with different implications for environmental impact and quality. Therefore, any discussion of economic growth and the environment can greatly benefit from a systematic and disaggregated study of a particular economy and the material links between the economy and the environment which support it.

It is a primary purpose of the model that we are building in the Ministry of the Environment to permit a detailed analysis of the relations between economic growth in Ontario, and the flow of materials to and from the Ontario environment in the form of wastes and material inputs. To accomplish this we are extending a model of the Ontario economy, that has been constructed in one of the other Ontario Ministries, to accommodate these material flows which affect the land, air and water of Ontario.

In view of the wide variation in the types and quantities of materials used and discharged by each of the industries in Ontario, it has been necessary for us to base our model on the only economic model for the Province which explicitly recognises the many different industries in Ontario. This model is known as an input-output model. Input-output models are distinguished from other economic models by the relatively high level of disaggregation and detail that they allow.

Since as many as 130 industrial sectors are distinguished in the current input-output model for Ontario, it is possible for us to consider the different environmental impacts in terms of material requirements and discharges, for each of these 130 industries. Consequently, when we come to consider economic growth over a period of a decade, we are able to take account of the growth of each of these sectors individually and to recognise the substantial variation in the environmental impact of economic growth, depending on what happens to each of the 130 sectors in the economy.

Before I attempt to describe the structure of our model in more detail and to consider some of its implications for policy making, I want to emphasise one more important feature of the input-output model which forms the economic core of our own model. It is some-

times suggested that there is no need to examine the entire economy for the purpose of environmental analysis since we already know the key industries when it comes to pollution and raw material requirements. With this knowledge, it is argued, we can direct our attention to each industry independently and base our estimates of future waste discharges and raw material requirements solely on the individual analyses of these industries.

Whilst there is an obvious need for single industry studies, there is the problem that if we fail to consider the interaction among industries, in terms of their requirements from each other, we have no way of knowing whether our forecasts of their future growth are mutually consistent. Growth in one industry requires an increase in its inputs that are supplied by other industries, which in turn, have their own input requirements, some of which may come from the first industry we considered. Each industry provides a market and a source of supply for each other industry in the economy and these inter-industry relations must be allowed for in one way or another in any approach to industrial forecasting.

In input-output models the driving force is consumer demand. Thus, growth in the market for automobiles obviously implies growth in the automobile industry. It also implies growth in all the industries which provide the automobile industry with inputs of finished and semi-finished goods and services. These industries which supply the automobile industry also require inputs from each other as well as inputs from the automobile industry. It follows, therefore, that the expansion of one industry to meet a growth in demand for its product sets up reverberations throughout the economy. These reverberations are fully accounted for in the input-output model. The essence of our work in the Ministry of the Environment is to acknowledge that, with each surge of industrial output that is induced by an increase in the demand for goods by consumers, there is an associated requirement for water and raw materials and a discharge of waste product.

Our preliminary results indicate that, for many industries in Ontario, the direct discharge of wastes associated with the production of goods for sale to consumers is often less than 50% of the total discharge of wastes when all the repercussions affecting the industries and the wastes they discharge are taken into account.

Turning now to a more detailed description of our model, there is an outline of the framework of the model in the third column of the accompanying chart. The dashed line half way down the page indicates where the basic economic input-output model ends and where the

modifications for determining the environmental impact of the economy begin. Essentially, the economic model predicts the industry outputs in terms of sales dollars which are necessary to supply forecasted or predicted levels of final demand. This final demand is made up of the demands of consumers, government and capital expenditures by business. In the Ontario input-output model the trade balance for each industry in Ontario with respect to the rest of the world is also included in final demand but the reason for this need not detain us here.

On the basis of a forecasted or projected level of final demand for each industry, the input-output coefficients are used to estimate the level of output for each industry which is needed to meet both the final demand for output as well as the intermediate demand by the other industries which require industrial output as an input into their production processes. These input-output coefficients, which are expressed in dollars of input per dollar of output, are derived from data collected for a particular year.

Providing each industry's requirements from each other industry does not change unduly from year to year, it is possible to use the input-output coefficients estimated on the basis of one year's data for calculating the output of each industry that will be needed to meet the final demand of future years. It is quite feasible, of course, to adjust the input-output coefficients for expected changes in industrial requirements and it is hoped to do this for Ontario as soon as new data become available. For the time being however, we are working with input-output coefficients that are assumed fixed during the forecasting period.

The input-output coefficients, which are a direct reflection of the industrial structure of the Province, link final demand to industry output. This is true whether the final demand is forecasted, or merely projected. Forecasted final demand is the final demand that is expected to prevail during some future year. Projected final demand is any pattern and level of final demand for which we wish to know the industrial output at the sub-Provincial level.

For each region in the model we are estimating waste load coefficients and water use and raw material coefficients, in terms of tons or gallons per dollar, for each industry. By applying these coefficients, which can change from one year to the next, to the regional industrial outputs, we arrive at estimates of the regional waste loadings, water use and raw material requirements, that are associated with the forecasted or projected level of final demand from which we began.

This then is the basic framework of the model, At present we are dealing with 49 industrial sectors, but we intend to disaggregate this into 130. It should be understood, of course, that the entire economy of Ontario is included in both levels of aggregation. The difference between them is the level of detail we can use in analysing the inter-industry relations within the economy.

We are currently working with 9 regions which represent the 9 major river basins in Ontario, and we have 16 categories of waste discharges. Both of these will be expanded in the near future. To date, we have not yet included water use and raw materials in the model but we intend to do this shortly.

As we have seen, there are several key links between final demand and regional environmental impact in terms of waste loadings and material inputs. The second column of the chart lists some of the more important factors which affect these components of the model. Thus, we see that any growth of demand in the economy, whether it be expected or desired, is registered in the model as forecasted or projected final demand. Changes in production methods and pollution control which affect the requirements of an industry for inputs from other industries per dollar of output, necessitate changes in the input-output coefficients. The location coefficients are directly influenced by changes in the location of industry within the Province. Finally, there may be changes in pollution control and production methods which alter the waste loadings and the water and raw material inputs per dollar of industrial output.

Each of these changes noted in the second column of the chart may come about for a number of reasons, one of which is in response to government policies. In the first column, therefore, various policy instruments are listed to show the way in which their environmental effects can be examined with the use of the model. By influencing the growth in demand in Ontario, Federal monetary policies and Federal and Provincial fiscal policies will have an effect on the residuals and raw material requirements of Ontario industries. These policies include changes in the level of interest rates and credit availability as well as in the type and level of taxes that are levied.

The inter-industry requirements in Ontario may also be influenced by monetary and fiscal policies. More directly, however, these requirements are affected by specific government programs of loans, grants and subsidies which are intended to aid particular industries. If these forms of financial assistance are made available only in selected regions, as part of a broader policy of

regional development, then they will affect the location of industry in the Province. The location coefficients, therefore, must be responsive to the government's land use planning policies and regional development incentives.

The policies mentioned so far have only an indirect effect on the environmental impact of the industries in Ontario. This is in contrast to the regulations and financial assistance and incentives to industry which are directed specifically towards pollution control, water intake and the extraction of raw materials from the environment. Changes in these government policies are introduced into the model by means of changes in the appropriate waste load, water use, and raw material coefficients.

With the model set up in the way I have described, a number of interesting questions can be addressed:

(i) What are the regional implications for waste loadings, water use and raw material requirements of the expected growth of the Ontario economy during the next decade?

To answer the question, final demand over the decade must be forecasted and changes in the various factors which influence the components of the model must be anticipated.

(ii) What other patterns of environmental impact are consistent with the expected growth of the Ontario economy?

It is possible to test the sensitivity of the environmental impact predicted by the model to changes in the location coefficients, the waste load coefficients and the water and raw material coefficients. By this means, ways may be found of achieving the expected growth in final demand with a reduced level of environmental impact. This may require changes in pollution control and production methods and changes in the location of industry.

(iii) It may appear that there is no way of meeting the expected final demands over the next decade without incurring an unacceptable level of environmental impact. The question then arises of how changes in final demand from that which is expected might reduce the environmental impact of industry.

The model is very able to cope with this sort of question because it not only allows us to examine the environmental impact of alternative projections of final demand, but it facilitates estimates of the environmental impact associated with the output from each industry, taking account of the indirect as well as the direct environmental impact of each industry. This information

makes it possible for us to determine which elements of final demand can safely be expanded and which should be subject to some sort of control via government policy.

I shall refrain from citing the very preliminary results that we have so far obtained from the model which we are building in the Ministry of the Environment. At present, the model is in little more than a pilot stage. It is hoped, however, that when we have completed our collection of data for the model, even in this early stage of its development, we shall have sufficient results with which to justify more extensive work in this area. One thing we have ascertained is that as research projects go, the cost of building the kind of model I have described is not excessive.

Furthermore, I should acknowledge that once completed, the model will remain very much an economic model, albeit an extended one. We are not modelling the environment but only what industry takes from it and what it puts back. If we can achieve a sufficiently high level of detail, with respect to the location of the environmental impact, it may be possible to integrate the model with other models of lakes, rivers and air sheds. In the meantime, however, we shall have to rely on a rather qualitative assessment by others as to the environmental effects of the waste flows and material requirements that the model predicts.

Finally, it will be recognised that the model does not include waste and material inputs associated directly with the consumption of output but only with the industrial activity necessary to meet the final demand. These and other environmental impacts, such as those from municipal sewage treatment plants, which are presently omitted, must be brought into any overall account of the interactions between the economy and the environment in Ontario. It is not yet clear whether the best way to do this is to extend the model to accommodate these other sources of environmental impact or to build separate models and to integrate the results. Nevertheless, these are the directions in which this part of our research in the Ministry is going and I hope that they are of interest to you.

June 26th OUTLINE FOR 'AN ECONOMIC AND ENVIRONMENTAL MODEL FOR PLANNING AND FORECASTING'

DR. P. VICTOR

GOVERNMENT POLICY INSTRUMENTS

FACTORS INFLUENCING MODEL COMPONENTS

FRAMEWORK OF MODEL

Monetary and Fiscal Policies

Growth in Demand

Financial Assistance to Industry

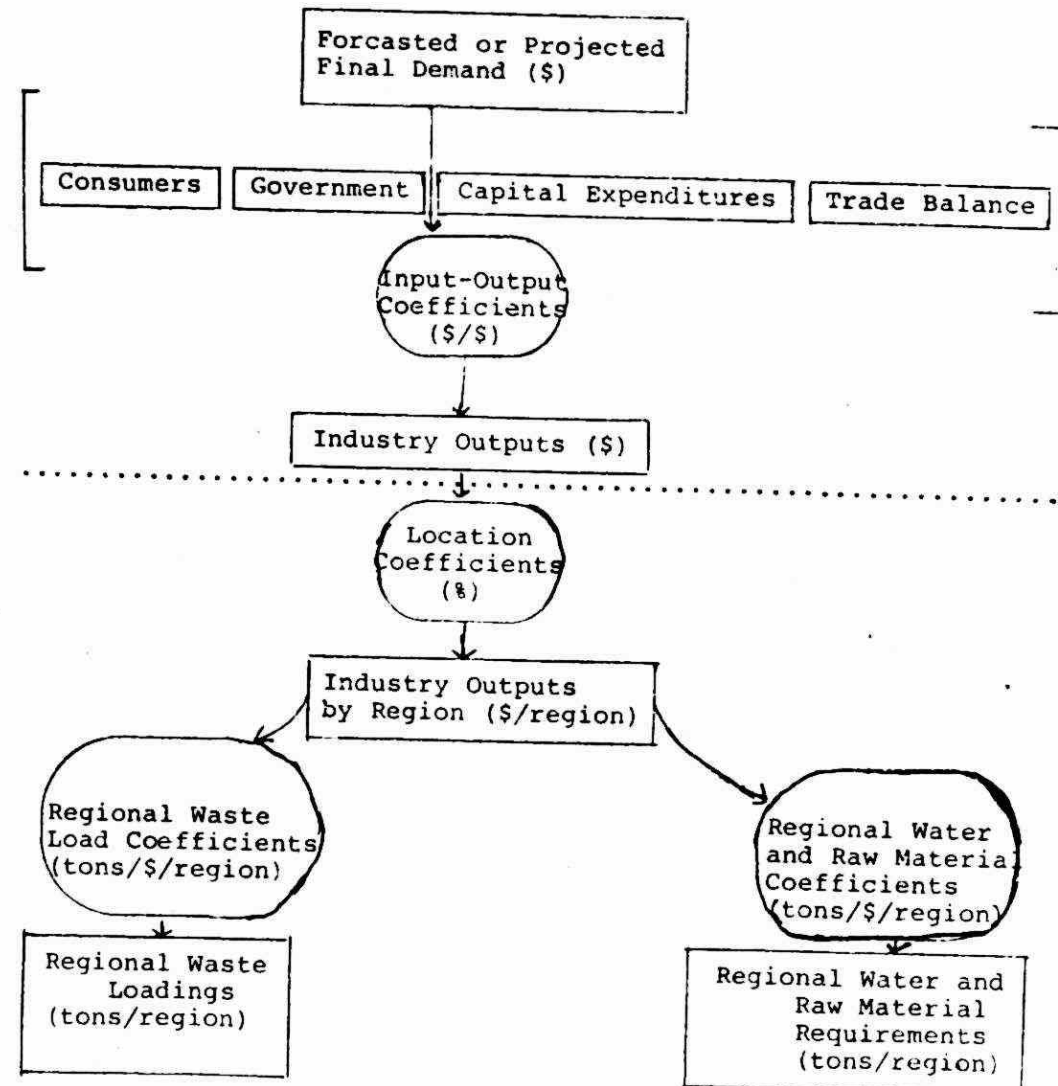
Changes in Production Methods and Pollution Control

Land Use Planning and Regional Development Incentives

Changes in the Location of Industry

Regulations and Financial Assistance and Incentives to Industry

Changes in Pollution Control and Production Methods





W. G. DALLAS

"Construction and Operation of a Mining Complex in an Urban Area"

BY

Mr. C. H. Frame
Vice-President & General Manager
Tara Mines Limited
Navan, County of Meath, Ireland

Paper Presented By :
Mr. W. G. Dallas

INTRODUCTION

Pragmatism has no place in a mining company's approach to environmental protection. If an environmental control program is to be successful it must, at the outset, arise from a sound social responsibility philosophy.

These are, of course, generalisations but they are justified by the experience of Tara Mines in its effort to minimise the natural and social environmental impact of Europe's largest base metal mining operation on a scenic, densely populated, highly productive agricultural area in the east of Ireland.

The town of Navan is situated within thirty miles of Dublin, Ireland's capital city and is the County and largest town of Meath. It is well served with road and rail transport, has good social facilities, good schools and from its existing resources can meet most of the requirements of a new mining community. From its population of roughly six thousand people the town supports almost fifty furniture manufacturing industries and a major carpet factory. There is virtually no unemployment and there is no real poverty, principally due to the proximity of Dublin city and the developing industrial town of Drogheda, 16 miles to the East.

The Rivers Boyne and Blackwater meet in the centre of the town and both are rated highly in Ireland for salmon and trout fishing, reflecting the high water quality of both rivers.

The town is surrounded by large farms producing beef, milk and grain and whose average acreage is high by Irish standards. The county of Meath, in which Navan is situated, is an important centre for the Irish blood-stock industry, which produces horses of world renown.

The county abounds with monuments of great historical value. Coincidentally, within five miles of the town of Navan, is situated the Hill of Tara - the traditional home of former High Kings of Ireland. It seems prophetic that almost twenty years before the discovery of the Navan ore-body, the founders of the Company named it "Tara Mines Limited."

The presence of zinc-lead mineralisation near Navan was discovered by Tara Mines Limited in 1970 and, since then, a program of diamond drilling has proven that a large orebody exists. Detailed studies have indicated that the orebody is amenable to conventional underground mining and milling practices.

The economic minerals are sphalerite and galena in a fine grained and intimate mixture. The Zn/Pb ratio is about 4.8:1.0 average. The associated minerals are pyrite with marcasite and barite with very rare specks of fluorspar. Silver is present in association with the galena at about 0.83 to 7.6 ozs/ton in flotation test concentrates and is expected to be recoverable. The gangue minerals associated with the ore are dolomite, calcite and silica. Dolomite is the host rock to the ore.

The mine is located within 2 miles of the centre of Navan town in a rural residential area. There are 40 dwelling houses on the immediate perimeter of the site and, nearby, a hospital and several schools. The Blackwater river flows over the orebody and the surrounding land is flat and generally without relief. The development shaft, the most northerly point of the development, is situated within 100 feet of a busy arterial road. (Figure 1)

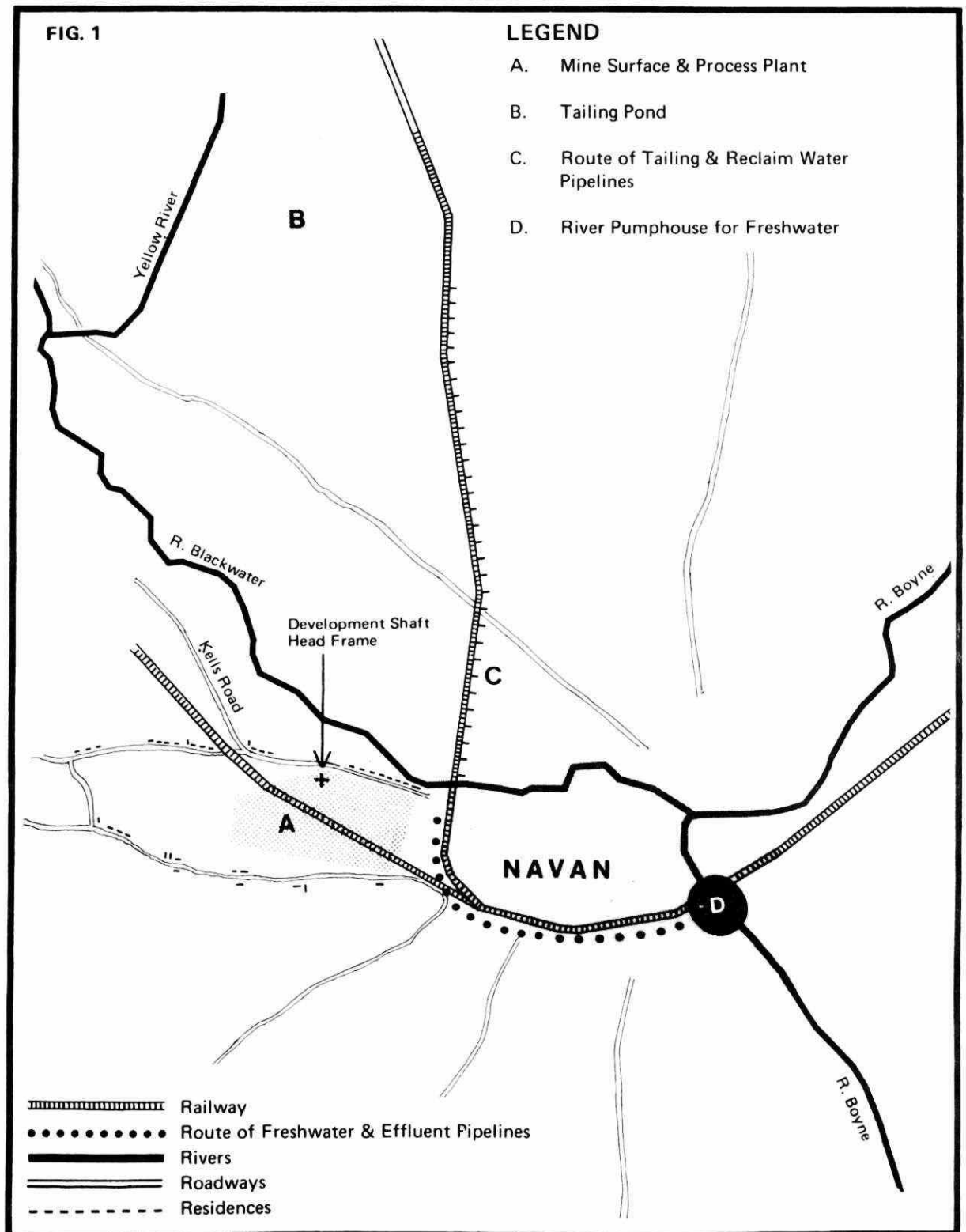
The mine, as designed, will produce 470,000 tons of zinc and lead concentrates per annum, necessitating the handling of $2\frac{1}{2}$ million tons of ore. In terms of financial return, its annual production will be valued at \$100 million or the equivalent of almost 2% of Ireland's gross national product. All mine workings will be underground, and the development of the surface complex represents the largest single industrial investment ever undertaken in Ireland up to this time.

It is hardly necessary to spell out the potential environmental conflicts in a marriage between this natural and social environment and an industry of the size envisaged. The level of justifiable apprehension which exists in the local community must also be appreciated. This fear is highlighted by the fact that Ireland has no mining tradition. The industry has only been in existence in a developed form for a decade and mines currently in operation are in fairly isolated areas. The only forms of mining with which most Irish people are familiar are quarrying for limestone, quarrying for construction and road aggregate and coal mining in Britain.

FIG. 1

LEGEND

- A. Mine Surface & Process Plant
- B. Tailing Pond
- C. Route of Tailing & Reclaim Water Pipelines
- D. River Pumphouse for Freshwater



Concentrate from the Navan mine will be shipped from a new jetty facility on the Boyne Estuary about 20 miles to the east, via an extended existing rail link. The lower stretches of this estuary contain a valuable mussel resource and a salmon fishery, both of which have been fished locally from historic times. Approximately 15% of the mussel area will be affected adversely by dredging necessary to accommodate ships. Salmon fishing will be undisturbed. The reduction of the mussel fishing potential could affect the livelihood of some 30 families.

It is within this economic, natural and social environment that Europe's largest base metal mining operation is being developed.

DESCRIPTION OF THE PROJECT

Site Description

The mine and process facilities, of necessity, are located close to the orebody. The principal objectives of the site arrangements are two-fold:

- (a) to achieve the optimum solution for operational efficiency, economy of construction and maintenance, and to allow for later modification and expansion; and
- (b) to satisfy the most exacting environmental and aesthetic requirements.

The layout of the mine and plant is illustrated in Figure 2. The mine facilities comprise: a decline portal, the development shaft with compressor house, a production shaft and three ventilation raises. The process plant is located in the centre of the site. The layout follows a functional arrangement of the process flowsheet from the covered coarse ore storage area through to the concentrate loadout, and it parallels the railroad spur which divides the site. Possible future plant expansion has been provided for in the arrangement. The back-fill plant, the mine substation, the fuel oil storage tanks and the sulphuric acid storage tanks are located close by the concentrator building.

The workshops and warehouse are located between the plant and the mine. The administration building, the assay and environmental control laboratory and the change-house are opposite the concentrator and adjacent to the main entrance to the site.

Run-off water from the catchment area above the mine site is collected in cut off trenches and diverted around the mine area. Within the mine area a system of ditches is constructed so that the drainage from the whole of the plant site is collected in the site drainage pond, from where it is pumped to the tailings pond.

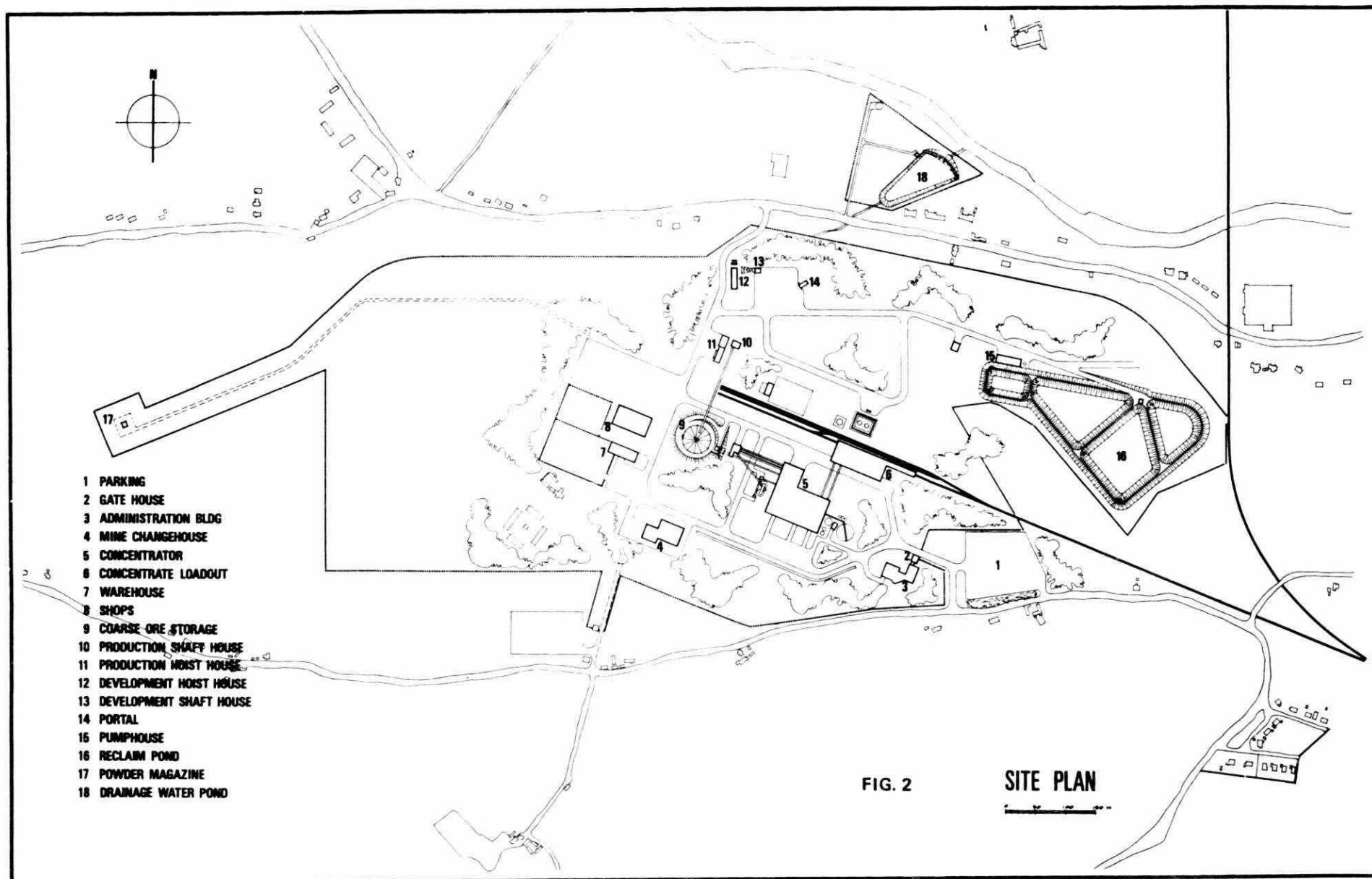


FIG. 2

SITE PLAN

All active mine property areas are carefully fenced. This fence is integrated within the landscape plan, with considerable care taken to make it unobtrusive. Where possible, it will be contained within planted areas and in trespass prone situations it will be supplemented by landscaped blocks of impenetrable spiny ground cover shrubs.

A system of primary and secondary roads connects all the mine facilities. All road surfaces on the site are tarmacadamed. These roads are provided with separate drainage channels which drain into the tailings pump box for pumping to the tailings pond.

The main railroad spur into the concentrate load-out is placed on the bed of a disused railway track which runs diagonally north west across the site.

Underground Mine Layout and Operation

It is planned to extract the orebody by conventional underground mining techniques. These are chosen to best suit the geological conditions and to optimise mining practice. Backfilling is employed on a systematic basis to ensure the stability of the underground workings and the overlying limestone beds.

Orebody Access and Ore Transportation

Access to the mine for men, materials and services is by a 1,000 feet vertical development shaft and a decline roadway driven at a slope of 20% to approximately the same depth. After primary crushing, ore is hoisted to the surface from underground via the production shaft. Men and materials are transported underground by the decline roadway in rubber tyred mobile equipment.

Ore hoisted to the surface via the production shaft is dumped into a hopper which discharges on to a totally enclosed conveyor leading to the coarse ore storage building.

High volumes of ventilation air will enter underground workings via the decline roadway and development shaft and, after use in mining areas, will pass to surface via specially bored raises. These raises are equipped with exhaust ventilation fans, which are located underground to satisfy noise control limitations.

Mine drainage water collects in large capacity underground sumps where solids settle out, prior to pumping via the development shaft to the tailings pond.

Description of the Process Plant

The process plant is designed to be operated continuously. Conventional milling and flotation processes are used to physically separate the zinc and lead from the limestone host rock.

Crushed ore from underground is stored in a coarse ore stockpile with a capacity of approximately 20,000 tons. This stockpile is totally enclosed within a building.

Ore is reclaimed from the coarse ore storage building and is conveyed to the crushing and screening plant located inside the main plant building for further crushing. The crushed ore passes to the fine ore storage bins.

The processes which take place within the concentrator building include; crushing, wet grinding, flotation, and filtering and drying of the lead and zinc concentrates.

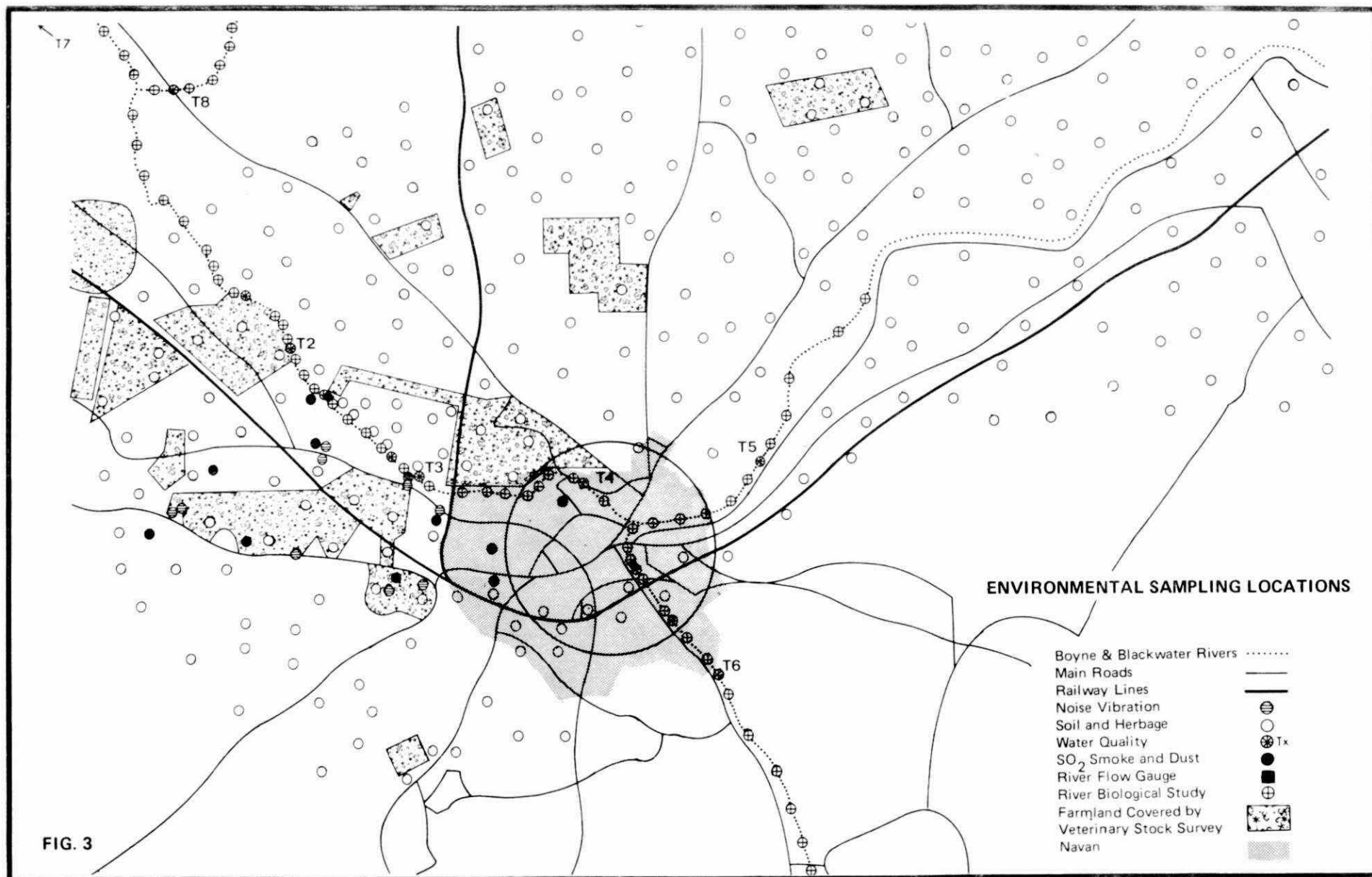
Fine ore from the storage bins is ground in rod and ball mills in closed circuit with cyclone classifiers. The ground material consists of a pulp of fine ore particles mixed with water.

This pulp is pumped to the flotation section where the actual separation of the zinc and lead minerals from the limestone takes place. The pulp is mixed with flotation reagents to render the lead minerals into a floatable condition. The lead minerals are then concentrated into a froth in banks of rougher, scavenger and cleaner flotation cells. The zinc minerals, which have been depressed during the flotation of the lead minerals, are activated by other reagents and floated in a similar circuit of flotation cells.

The dewatering of the concentrates is accomplished in three stages of thickening, filtering and drying. The zinc concentrate is leached in agitators with sulphuric acid to remove residual dolomite. The concentrates are filtered and partially dried in oil fired rotary driers to approximately 8% moisture. The partially dried concentrates are conveyed to an enclosed storage and rail shipment building for storage prior to loading on railway wagons.

Tailings Disposal

The residue remaining after the flotation of the lead and zinc minerals contains the dolomite and limestone host rock with which the minerals were originally associated. This tailings, which constitutes some 80% of the ore feed to the process, is first pumped to the backfill plant, where the coarse sand fraction is extracted and stored in silos before being mixed with cement and pumped into worked-out areas of the mine as cemented backfill. Residual tailings are pumped to the tailings pond through a three mile long pipeline. (Figure 1)



BASELINE NATURAL ENVIRONMENTAL STUDIES

Detailed knowledge of the existing environment is essential before conservation planning for a new development can commence. This chapter describes the baseline environmental studies undertaken for the Navan project and summarises their results. The information obtained provided valuable data for the project designers and baseline datum levels for future comparison.

River Water Chemical Surveys

The catchment areas of the River Boyne and Blackwater are relatively unaffected by industrial pollution. There are, however, localised problems of minor consequence.

Regular and comprehensive monitoring of the water chemistry at a number of selected stations on the Blackwater, Boyne and Yellow Rivers near Navan has been undertaken to determine the premining background levels of soluble inorganic ions, organic material and suspended solids. This information provided useful data for selecting the point of discharge of mine waste water, as well as for specifying water quality standards for the mine discharge and for designing waste water treatment facilities.

In a comprehensive review of sampling programs for rivers and effluents, Montgomery and Hart (1974) recommend that 6 samples per cycle be regarded as an acceptable working frequency for defining cyclic variations. Thus, to evaluate the effect of seasonal variations on water quality subject to natural changes, samples of river water should be taken at least monthly. Since 1972 the Company's surveys have been undertaken on a regular monthly basis at six selected stations T2, T4, T5, T6, T7, T8 on above rivers, as shown in Figure 3.

The results are presented in Table 1. Apart from the localised effect of domestic, farming and light industrial discharges, the present water quality in the three rivers, as shown in Table 1, is excellent.

River Biological Survey

A biological survey of the Blackwater and Boyne Rivers was undertaken during October, 1972, to establish the late summer baseline biological conditions. This information was supplemented by data from An Foras Forbartha* on the macro-invertebrate communities of these rivers and their tributaries. The baseline study also included an investigation of the flora distribution in both systems. These surveys established that, biologically, the rivers are highly productive.

*The Institute for Physical Planning and Construction Research - an Irish Government sponsored body.

Fishery information was provided by the Irish Department of Agriculture and Fisheries. The Company is engaged in a continuing research program on the fisheries in the Blackwater, Boyne and Yellow rivers to obtain data on species, age and biomass.

Annual reports of the Department of Agriculture and Fisheries confirm that both the Blackwater and Boyne Rivers have a good and longstanding reputation as fishing rivers. The Boyne is considered to be one of the best early salmon rivers in the country. From the beginning of the season in February up to early May catches average 16 - 18 lbs. with a few fish up to 30 lbs. The size of fish caught gradually decreases until, in July, the average fish weighs about 9 lbs. From July to September some grilse (fish which have spent one year in the sea) are taken and these average 5 - 6 lbs. in weight. The run of both grilse and sea trout is small.

A few salmon are taken in the Blackwater with occasional large catches in one particularly valuable fishing area between the mine site and the town.

A spawning run occurs in late September and throughout October, when the fish move to the upper reaches of the Boyne and its tributaries. A small run of spawning fish may also occur in January. After two years of river life, the smolts descend to the sea in May or June. Annual returns for salmon and trout in the Boyne area are given in Table 2. These figures, however, underestimate the total catch because of incomplete returns.

There is little commercial fishing for sea trout and they are normally caught as a by-product of salmon fishing. There is a long record of eel fishing in the Boyne and Blackwater. The eels are fished as fully grown adults having spent 6 - 10 years in the rivers.

River Hydrology

This survey was particularly important as the flow in the river at different times of the year will influence the withdrawal of river water and the return of clear discharge water from the mine. River flow records, compiled over the past 30 years, were studied with particular reference to low flow periods.

Flow frequency curves for the Boyne and Blackwater rivers during the drought years 1959 and 1969 (Figures 4a and 4b) show that the Blackwater would not have an adequate supply during low flow periods for abstraction by the mine. However, the investigation showed that the Boyne above Navan could supply the desired 2,000 US gallons per minute (4.5 cusecs) of fresh water makeup for the mine even during the lowest flow periods, while maintaining adequate minimum flows in the Boyne.

Fig. 4a TYPICAL FLOW FREQUENCY CURVES OF THE BLACKWATER RIVER

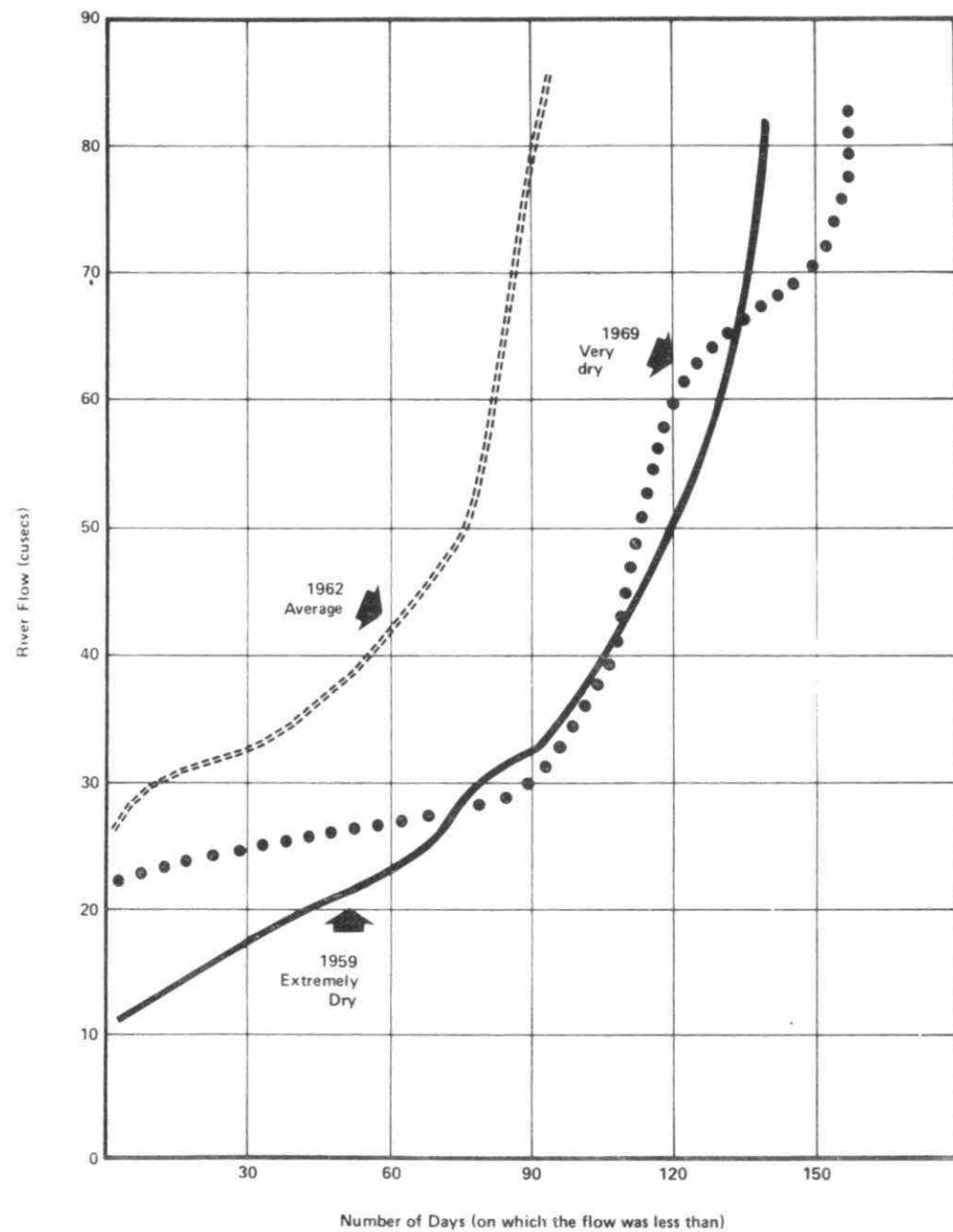
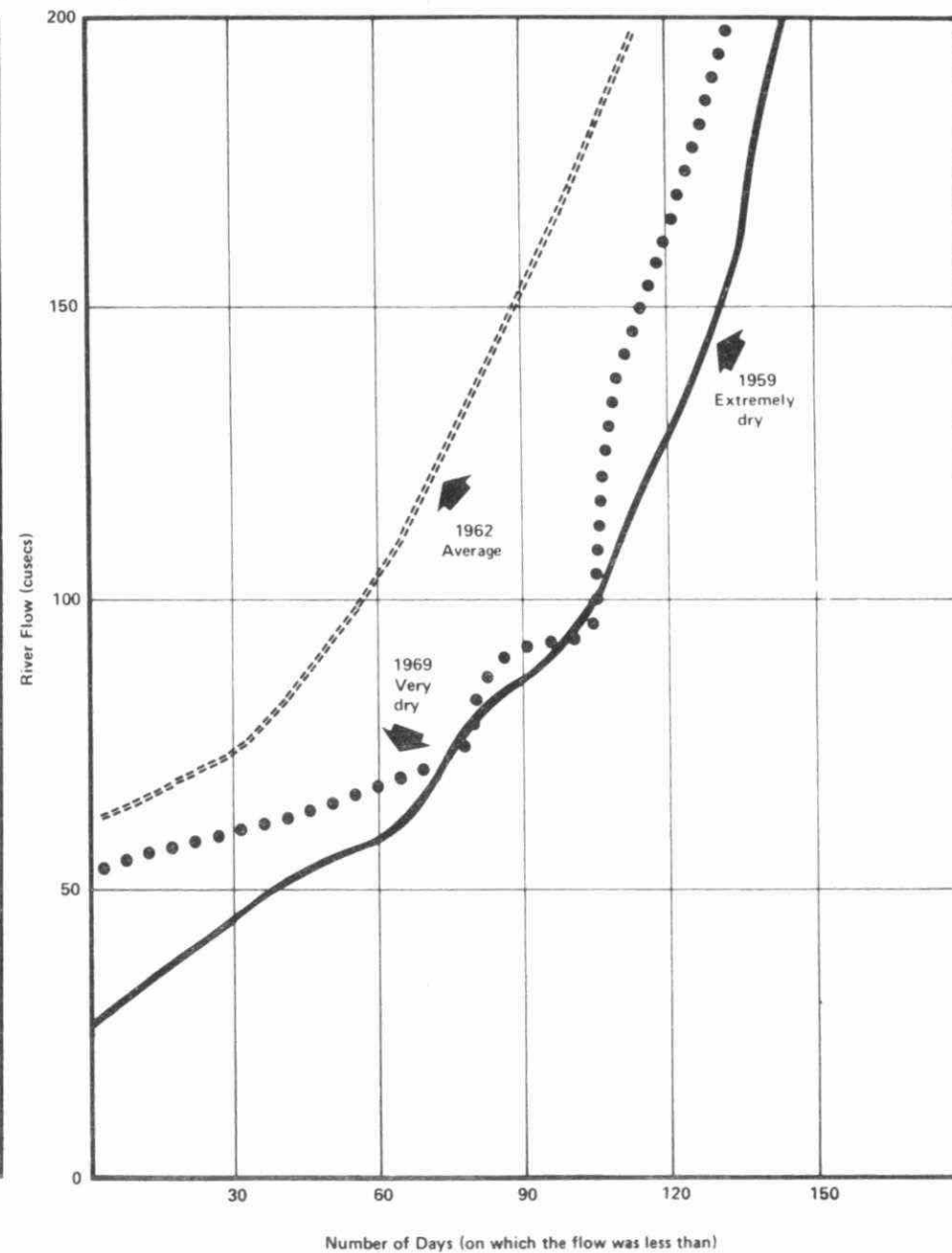


Fig. 4b TYPICAL FLOW FREQUENCY CURVES OF THE BOYNE RIVER UPSTREAM OF NAVAN



Because of the higher flows in the Boyne and the greater hardness of this water, providing increased protection to river fauna and fish species, it was decided to pipe the treated mine water discharge more than one mile to the Boyne rather than the adjacent Blackwater River.

TABLE 1

WATER ANALYSES OF BLACKWATER, BOYNE AND YELLOW RIVER
FOR TARA MINES SAMPLE STATIONS

Parameter	Sample Station No.	T2	T4	T5	T6	T7	T8
PH		8.0	7.89	8.08	8.07	7.88	8.02
Alkalinity (As mg/l CaCO_3)		133	136	237	255	170	290
Total Hardness (As mg/l CaCO_3)		146	152	289	322	185	311
(COD (mg/l))		5.1	5.4	5.4	4.8	6.2	3.4
BOD(mg/l)		0.7	1.1	1.4	1.1	1.1	1.6
Suspended Solids (mg/l)		9	9	30	34	14	22
Total Solids (mg/l)		223	249	415	488	235	476
Ash (mg/l)		147	158	305	345	167	313
Ammoniacal Nitrogen (mg/l N)		0.228	0.175	0.199	0.166	0.145	0.151
Nitrate Nitrogen (mg/l N)		0.989	2.711	2.348	1.758	0.425	0.950
Sulphate (mg/l)		17	20	37	47	19	31
Zinc (mg/l Zn)		0.028	0.029	0.025	0.036	0.011	0.008
Lead (mg/l Pb)		0.009	0.013	0.011	0.011	0.007	0.003
Copper (mg/l Cu)		0.010	0.020	0.016	0.019	0.011	0.006
Iron (mg/l Fe)		0.294	0.376	0.837	0.732	0.166	0.252
Chromium (mg/l Cr)		ND	ND	ND	ND	ND	ND

ND - not detected at 0.005 mg/l

TABLE 2

ANNUAL FISH RETURNS FOR THE BOYNE AND BLACKWATER RIVERS

Year	Weight (lbs.)		
	Salmon	Trout	Eels
1968	131,000	4,690	9,360
1969	77,820	7,760	38,020
1970	61,380	4,350	28,650
1971	62,364	6,241	13,214
1972	81,337	4,248	1,123

Soil and Herbage Surveys

A trace element survey of soil and herbage was carried out by An Foras Taluntais* in the Navan area. The aim of the survey was to establish the premining background levels of lead and zinc in soil and herbage samples. As the contents of these elements in herbage are known to vary with season, surveys were undertaken in August 1970 and February and August 1971. The herbage consisted of mixed grass species with relatively small amounts of clover in the August cuts. As well as lead and zinc, the soils were examined for silver and cadmium. The sampling locations are illustrated in Figure 3 and the results of these surveys are summarised in Tables 3 and 4.

The surveys have been extended to cover fields adjoining the route of the railway line between Navan and the shipping terminal on the Boyne Estuary. Soil and vegetation samples near the line in Navan will also be analysed for lead and zinc.

TABLE 3

SUMMARY OF SOIL ANALYSES IN NAVAN AREA

Value	Soil Analyses (ppm dry weight basis)			
	Pb	Zn	Ag	Cd
Maximum	4,000	2,930	4.3	21.8
Minimum	17	88	-	-
Median Values	30-70	110-180	-	-

TABLE 4

SUMMARY OF HERBAGE ANALYSES IN NAVAN AREA

Value	Herbage Analyses (ppm dry weight basis)			
	Pb		Zn	
	Summer	Winter	Summer	Winter
Maximum	9.0	193.0	250	754
Minimum	1.0	3.6	23	45
Median Values	1.5-3.0	6.0-9.0	30-50	50-80

Veterinary Survey

Concurrently with the soil and herbage survey a

*The Agricultural Institute - An Irish Government Sponsored Research Body.

study was carried out to assess, by means of certain biochemical parameters in blood and liver tissue, the mineral metabolism of the cattle in the area. The areas of the survey are shown in Figure 3.

In general the biochemical assays were within an acceptable range. Blood lead levels were low in the November survey while the spring lead levels were higher corresponding with increased herbage lead levels during this period. The autumn blood zinc levels were generally normal, although in some farms the values were noticeably higher than the normal values for the area. In the spring survey these cattle registered a higher than average blood zinc status, indicating the expected seasonal variation. The average levels of copper, zinc and lead in liver and blood samples are given in Table 5 for the two surveys.

Atmospheric Survey

Daily smoke and sulphur dioxide samples have been taken in the centre of Navan and the results are given in Table 6. Smoke and sulphur dioxide was measured by the method specified in British Standard 1747, Parts 2 and 3.

British Standard bowl and directional type dust gauges (British Standard 1747 Parts 1 and 5) have been installed at the locations shown in Figure 3 to monitor background dust levels, as well as the dust fallout during the construction and operation of the mine. Analysis of the dust samples in these gauges gives the monthly deposition rate of dust at each location as well as the zinc and lead concentrations in the dust.

Data from the directional gauges can be used to estimate the dust load emanating from the site. For example, four directional gauges are being deployed at about a $\frac{1}{2}$ mile radius from the mine site and at the four cardinal points.

The directions of the four collection apertures of each gauge are arranged on the N/S and E/W axes. Thus, the dust resulting from the mine site can be estimated from:

$$(a) \text{ West wind : } (1) W - \frac{((2)W + (3)W + (4)W)}{3}$$

$$(b) \text{ East wind : } (2) E - \frac{((1)E + (3)E + (4)E)}{3}$$

$$(c) \text{ North wind : } (3) N - \frac{((1)N + (2)N + (4)N)}{3}$$

$$(d) \text{ South wind : } (4) S - \frac{((1)S + (2)S + (3)S)}{3}$$

TABLE 5
SUMMARY OF VETERINARY SURVEY RESULTS

Group No.	No. of Animals	Age	Type	LIVER		BLOOD		
				Average PPM Cu	Dry weight Zn	Average Concentration Cu	Zn	PPM Pb
NOVEMBER SURVEY 1971								
1	7	1½ y.o.*	Freisan Heifer	85	138	0.04	.7	0.2
2	13	1/2 y.o.	Cattle	107	148	0.09	1.0	0.09
3	3	1 y.o.	Shorthorn Heifer	48	155	0.08	2.4	0.02
4	3		Cows 1st Calf	75	159	.10	2.4	0.02
5	12		Cows Freisan	136	153	.07	1.6	0.04
6	8		Calving heifers	38	153	.06	1.8	0.05
7	7		Cows Freisan Cross	22	131	.08	1.1	0.02
8	5	1½/2 y.o.	Cattle	29	175	.08	1.3	0.02
9	8		Cows Freisan Shorthorn	5	148	.07	1.7	.13
10	11	1½ y.o.	Bullock Freisan Cross	14	144	.02	1.2	.07
11	11	2½ y.o.	Bullock Freisan Cross	49	139	.07	2.5	0.02
12	7	9 m.o.**	Aberdeen Angus Bullock	44	148	.05	2.7	0.02
13	7	2 y.o.	Hereford Cross Bullock	10	137	.03	2.7	0.02
14	7		Yearling Freisan	42	132	.08	0.8	0.02
15	9		Cows Freisan	60	164	.03	0.7	0.02
16	10		Yearling Freisan	16	126	.07	1.6	0.02
17	10		Cows Freisan	33	122	.04	1.2	0.06
18	11	1½/2 y.o.	Hereford Cross	10	130	.07	1.2	0.14
19	2		Yearling Bullock	21	146	.08	2.0	0.02
20	7	1½/2 y.o.	Bullock mixed	37	173	.07	2.6	0.02
JUNE SURVEY 1972								
20A	12	1½/2 y.o.	Store Cattle	155	151	.07	3.1	1.9
14A	9	1½/2 y.o.	Store Cattle	137	157	.06	3.4	3.8

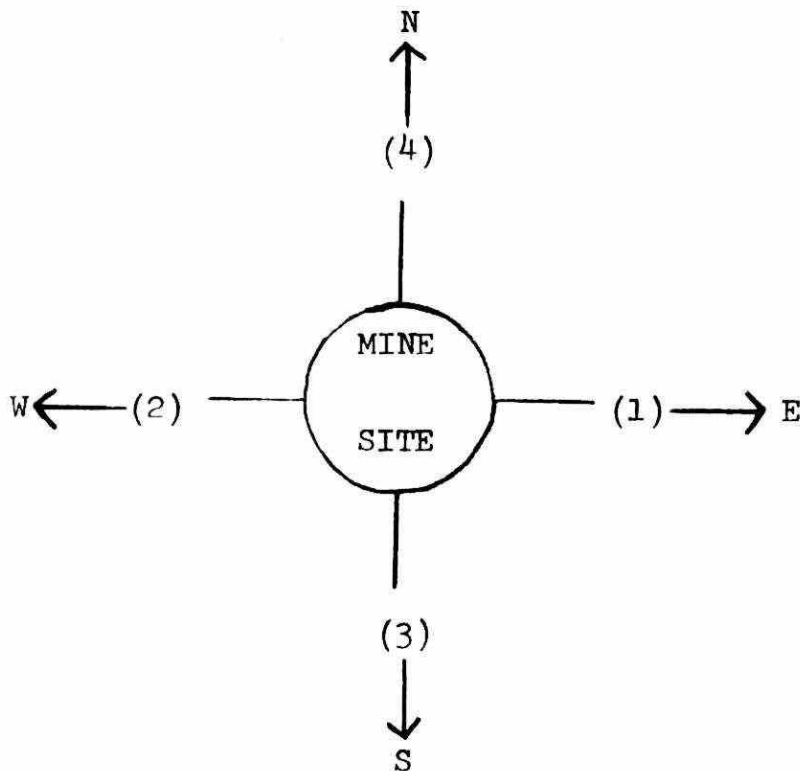
* years old

** months old

TABLE 6
SUMMARY OF ATMOSPHERIC SULPHUR DIOXIDE AND SMOKE CONCENTRATIONS IN THE NAVAN AREA.

Month	Sulphur Dioxide (µg/m ³)			Smoke (µg/m ³)		
	Average	Maximum	Minimum	Average	Maximum	Minimum
January	50	293	N.*	80	340	13
February	25	62	N.*	51	108	16
March	49	137	19	74	151	20
April	44	99	18	42	88	10
May	20	60	N.*	43	75	17
June	13	42	N.*	24	64	5
July	30	54	16	22	40	9
August	28	77	6	54	107	4
September	29	52	5	53	103	18
October	36	72	15	85	209	7
November	47	134	21	61	167	3
December	27	46	14	51	109	8
January	65	148	3	35	80	3

* N = Not Detected



Location of Dust Gauges relative to Mine Site.

Sound Survey

A sound survey was carried out which revealed that the neighbourhood of the mine contained a wide variety of noise climates ranging from the noisy environment of the busy streets and main roads in and around Navan to the quiet, rural residential and agricultural areas further out in the countryside. Measurements of noise levels were taken and the more sensitive areas in the neighbourhood of the mine were identified.

The site is bounded to the North by the busy Kells Road, where residents are exposed to traffic noise of passing vehicles of the order of 70dBA often reaching values of 90dBA and continuing into the late evening. Between 1a.m. and 5a.m. the noise level drops below 35dBA except for occasional interruptions by sporadic traffic.

On the southern boundary of the site, (i.e. along Knockumber Road), there is little traffic even during day-time. The background noise is rarely more than 35dBA and represents a very sensitive situation. It can be seen that night time operations on the site necessitate extensive noise abatement procedures and sensitive locations exist where even daytime noise has to be carefully controlled.

Domestic and Agricultural Water Surveys

In the absence of piped water outside the Navan urban district, individual houses and farms depend on

their own wells for an adequate water supply. During the major exploratory diamond drilling period in 1971/72, a survey of these wells was carried out to establish their output, depth and average water levels. Water levels in exploratory drill holes were also monitored concurrently.

Monthly surveys of well water quality were carried out in 1971/72 and these will continue on a monthly basis during the life of the mine to include analyses for copper, lead, zinc, iron, BOD, COD and total hardness.

Ground Water Studies

An initial investigation using 20 piezometers and also permeability tests was carried out prior to any major underground development. This established the permeability characteristics of the various strata and identified recharging aquifers.

This study and continuing investigations involving over 50 piezometers, will lead to effective ground water control measures in the development of the mine. Continuous monitoring of the piezometer level behaviour also shows the influence of underground development on ground water conditions and indicates likely problem areas in advance. The effect to date of mining operations on the water table in the area has been localised and relatively small.

Estuary Surveys

A monitoring program was completed in the area of the Boyne estuary adjacent to the shipping terminal. Mussels, estuarine mud and water were analysed to determine premining heavy metal levels.

CONTROLS INCORPORATED IN PROJECT DESIGN FOR PROTECTION OF NATURAL ENVIRONMENT

It was against a background of limited Government guidelines for controlling air and water pollution and noise emissions that the development of the Navan project was undertaken. Thus, it was necessary to seek the experience of other more developed and industrialised countries to provide internationally accepted environmental control criteria for designing this operation.

While the baseline studies are important in providing a scientific assessment of the premining condition of the Navan environment, the information obtained from the studies provided essential data for designing the mining operation to conform with the strict self-imposed environmental guidelines. This chapter highlights the design features incorporated into the process for controlling the disposal of liquid and solid wastes and exhaust gases and for limiting noise emissions.

Process Water Treatment and Disposal

All mill and mine waters are pumped to the tailings pond for primary treatment. Decant water is returned to the reclaim pond as shown in the process water flow diagram (Figure 5) and excess water passes through the clear water pond before discharging to the Boyne. Because of soluble constituents in this water at concentrations toxic to fish life, it is necessary to control the discharge rate to provide adequate dilution in the river over a wide range of flows.

The diluting capacity of the river is determined by (a) the background levels of toxic elements in the river water, (b) the concentrations of toxic elements in the mine discharge and (c) the desirable levels in the river water (i.e. water quality standards) to ensure the protection of sensitive fish species.

TABLE 7

LIST OF FLOTATION CHEMICALS WITH ANTICIPATED CONSUMPTION

Type	Estimated Consumption lbs. per ton ore	Short tons per year*
Sulphuric Acid	15.0	16800
Hydrated Lime	11.5	12880
Sodium Carbonate	1.5	1680
Reagent 242	0.075	84
Sodium Isopropyl Xanthate	0.03	33.6
Sodium Silicate	1.5	1680
Zinc Sulphate	1.05	1176
Sodium Cyanide	0.25	280
Copper Sulphate	1.25	1400
Potassium Amyl Xanthate	0.18	201.6
Reagent Z - 200	0.02	22.4
M.I.B.C. Frother	0.09	100.8
Cresylic Acid	0.02	32.4
Flocculant	0.02	22.4

Design Capacity of the Tailings Pond

The main function of the tailings dam is to provide adequate capacity for settling and retaining fine solids, and to provide sufficient retention time for the biological oxidation of residual flotation reagents.

The major proportion of the flotation reagents (Table 7) added in the mill is either adsorbed/absorbed on to the zinc/lead concentrates or on to the tailings solids, or reacts chemically in the process. Only a small proportion of the original reagents added remains in solution and is discharged to the tailings reservoir.

Adequate residence time must be provided under aerobic conditions to biologically oxidise the biodegradable organic flotation chemicals, so that the decant water

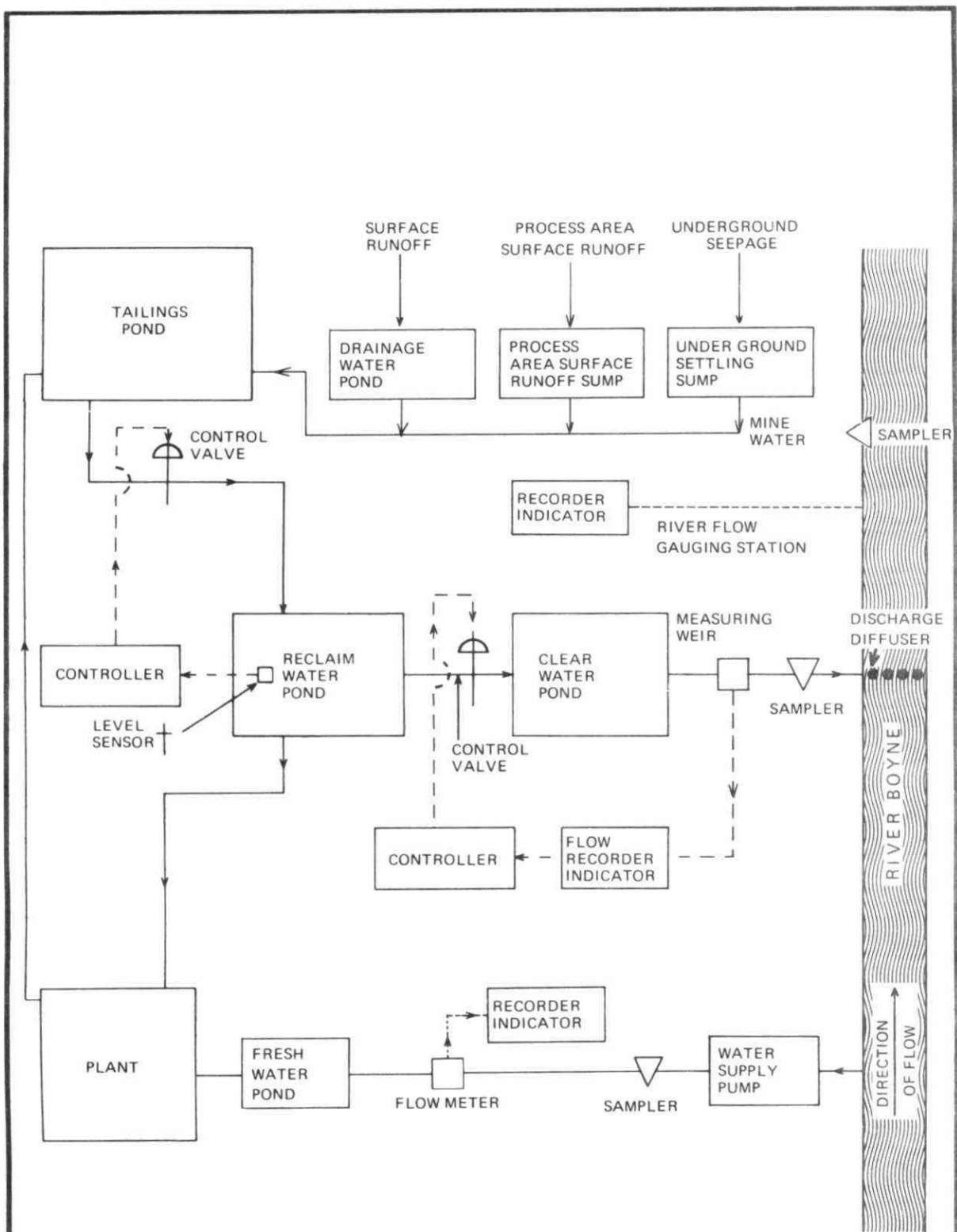


Fig 5 PROCESS WATER FLOW DIAGRAM

will be suitable for recycling to the mill as well as for discharge to the river. From simulated tailings pond tests and recycle calculations it is found that, during the summer months, a minimum residence time of 25 days should be provided, increasing to between 40-50 days during the winter months.

Another important function of this tailings pond is to provide buffer storage capacity for contaminated mine and mill water during periods of low flow in the Boyne, which usually extend from about June to October. From estimates of the water balance for the mine and mill under varying conditions, calculations of storage capacity requirements have been carried out for average and drought years. These calculations take into account the actual daily rainfall and run off which would have entered the pond, as well as the daily variations in river flows for the years 1941, 1959 and 1962, representing average, drought and average rainfall in those years.

From the graphs in Figure 6 it is noted that maximum water level variations in a 100 acre pond for average years 1941 and 1962, are 12ft. and 11ft. respectively, and for a drought year 1959, 14ft. In order to allow for the anticipated water level variations due to varying discharge rates, an additional 1,000 acre ft. capacity has been provided in the initial tailings pond design. Experience gained during the first few years operation of the mine will determine the buffering capacity required in the pond during succeeding years.

For control of seepage water from the tailings pond a ditch is constructed around the perimeter and collected seepage water is pumped back into the pond. Test wells are located at selected points outside the ditch as a further precaution.

Rehabilitation of the Tailings Area

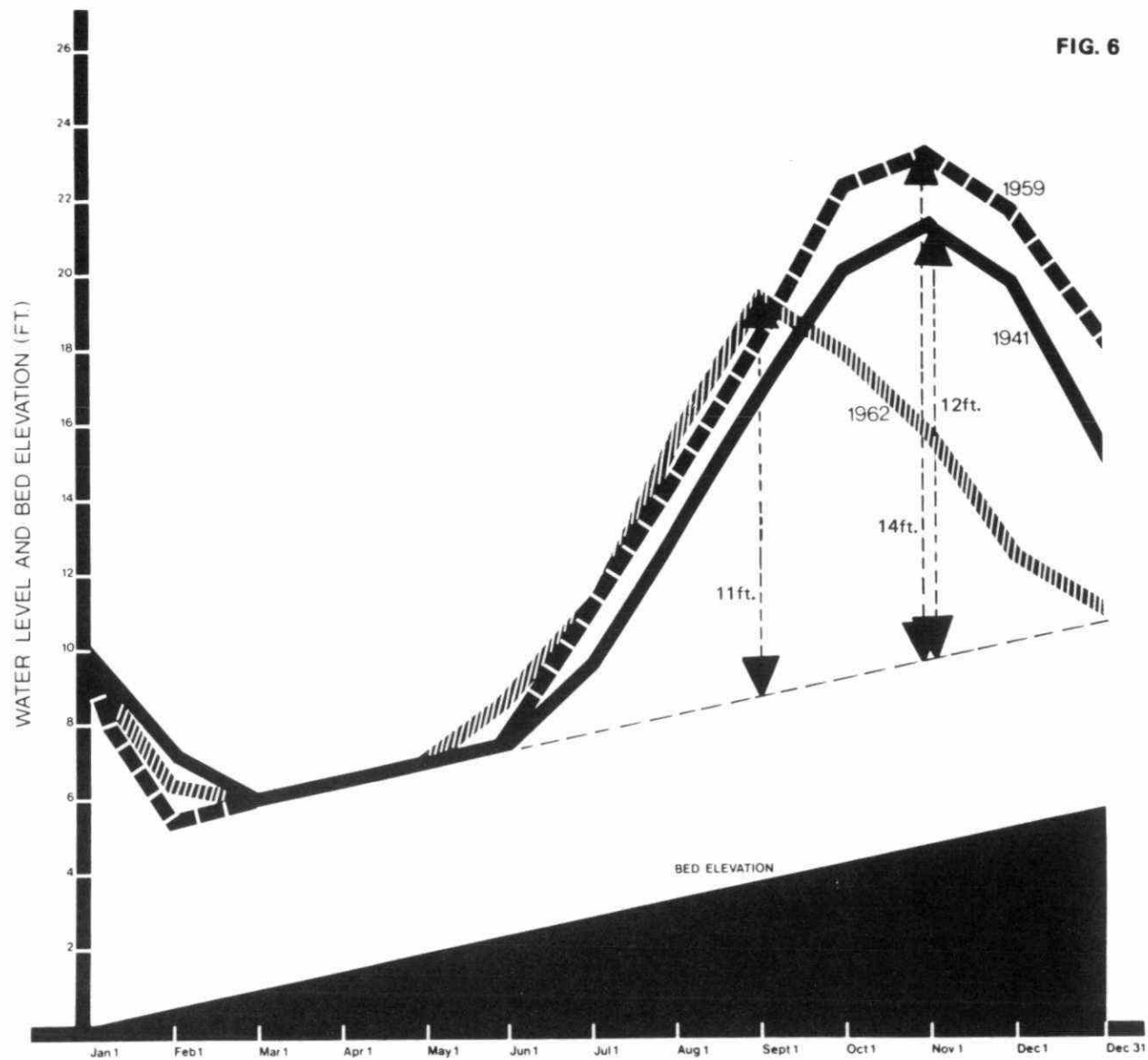
The actual revegetation process for the tailings media specific to Navan, is undecided. The Company, with its sister Company, Northgate Exploration, is, however, investigating the problems of tailings treatment and utilisation as part of a joint research program with Dublin University, (Jeffrey et al. (1974)). By the time the first stage of the Navan tailings area rehabilitation begins it is anticipated that techniques and treatment will have been well established at other mines within the Tara-Northgate Group.

Control of Treated Discharge Water

In deriving suitable limiting concentrations for heavy metal ions in the rivers it is necessary to make adequate provision to protect:

- (a) adult salmon and sea trout entering the rivers, and also their movement upstream to spawning grounds;

**Calculated
Variation in
Water Level of
Tailings Pond
of 100 Acre
Capacity**



(b) descending salmon and sea trout smolts on their way to the sea;

(c) river trout in the lower reaches of the Blackwater and Boyne;

(d) descending adult eels and ascending young elvers;

(e) the other fish and invertebrate fauna of the river which are an important source of food for the game fish.

The location of the spawning beds of salmon and sea trout and of river trout are upstream of the mine site at Navan. Therefore, the young stages, which are often the most sensitive to heavy metal ions, will not be affected.

During the past twenty years an extensive amount of laboratory and field research work has been carried out on the effect of soluble heavy metals on fisheries (e.g. Lloyd (1972)). Concentration limits are set to allow for the greater sensitivity of migratory salmon and sea trout, as well as behaviour and reproduction characteristics of these and other species. These standards also allow for such factors as temperature, pH and total hardness which influence the effect of these heavy metals on fish life and invertebrate species.

Laboratory and field tests have further shown that the toxicity of mixtures of certain heavy metals can be calculated from the toxicities of the individual metals by assuming that they exert a similar joint action. In the event of more than one metal being present, a guide to the toxicity to fish of the metals in combination may be obtained by adding the ratios:

$$\frac{\text{Actual concentration of metal}}{\text{Limiting concentration of metal}}$$

the sum of which should be less than one if the water is to be considered acceptable for fishery purposes.

From a detailed review of the literature, limiting concentrations for heavy metals listed in Table 8 were used to determine the design dilution necessary to safely discharge the mine effluent into the Boyne.

Using the detailed water chemistry data summarised in Table 1 and the above information, it is estimated that a dilution of 50:1 is required to protect the Boyne fisheries. The resulting concentration of heavy metals in the scale models of the manifold were used; Boyne river water after dilution by this amount also satisfies International Drinking Water Standards (World Health Organization (1971)).

The discharge rate from the final treatment pond will be monitored and controlled according to the

measured river flow and water quality of the mine discharge and the river to meet the above fishery and drinking water standards. The dilution ratio may be adjusted to suit the prevailing hydrological and chemical conditions.

TABLE 8

DESIGN LIMITING CONCENTRATIONS OF HEAVY METALS IN FISHING STREAMS AND MAXIMUM ANTICIPATED CONCENTRATIONS IN MINE DISCHARGE

Metal	Limiting Concentration (mg/l) (for hardness 300 mg/l CaCO_3)	Maximum Anticipated Concentration in Mine Discharge (mg/l)
Lead	0.5	0.2
Copper	0.1	0.2
Zinc	0.5	2.0
Cadmium	0.01	0.01
Arsenic	0.01	0.01
Chromium	0.01	0.01
Antimony	0.01	0.01

Hydraulic Design of Discharge Diffuser

The proposed discharge system is by means of a 100ft. long manifold, or flow distributor, laid across the Boyne river at bed level. This manifold has been designed to ensure very rapid mixing and dilution of the discharge water (Prosser (1974)).

Experiments on physical test rigs were undertaken to complement the theoretical design considerations and in particular to give guidance on the following aspects:

- (a) the choice of manifold area ratio (ratio of manifold pipe cross-sectional area to the total cross-sectional area of the nozzles) to give a satisfactory spanwise flow distribution;
- (b) the choice of nozzle angle to give a satisfactory depthwise flow distribution;
- (c) the head loss at the manifold.

Two different arrangements of 1/6 :

(a) Section Model

A short section (4ft. prototype) of the manifold, containing two outlets, was fitted into a perspex sided water channel 8 inches wide. This allowed a good view of the trajectory of the jet and the vertical mixing to be obtained by injecting dye into one of the nozzles during discharge.

Modifications to the nozzle and manifold sizes were made during the study but the main use of this facility was in arriving at the optimum nozzle angle.

(b) Full-span Model

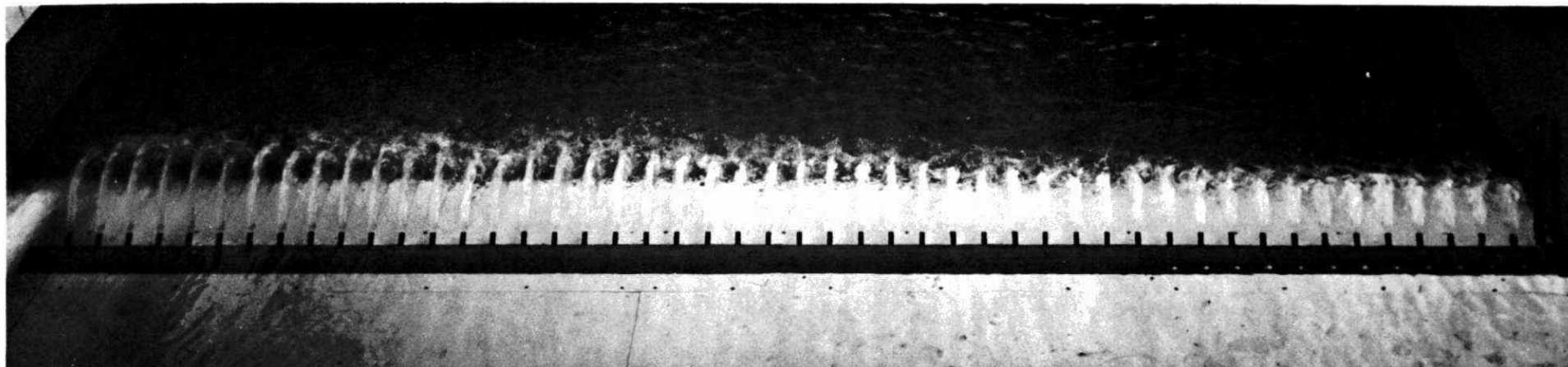
A 1/6 scale model of the manifold was built across a water channel 1 1/4 ft wide. The general arrangement is shown in Figure 7. The model manifold was made from 4 inch internal diameter PVC pipe with 48 nozzles 2 inches long, spaced at 3 1/2 inches between centres. Two sizes of nozzles were used - a nominal 0.5 inch diameter for the first tests and a nominal 0.4 inch diameter for the final arrangement. Provision was made for injecting dye into the discharge water so that the mixing downstream of the manifold could be observed. Alternatively, a weak salt solution was used for the discharge water and salinity measurements were made downstream from the manifold to give a quantitative measurement of the mixing.

For the final design configuration of the diffuser (Figure 7B) with a prototype nozzle internal diameter of 2.5 inch, the distribution of flows through the nozzles was much improved, compared with the initial 3 inch prototype nozzles (Figure 7A).

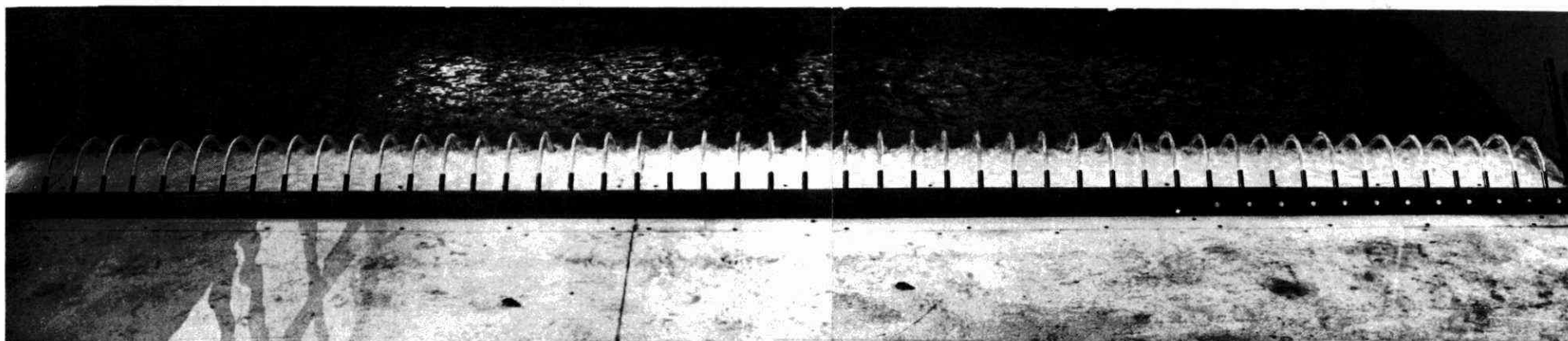
A series of tests was undertaken in the 8 inch wide water channel using the sectional model to study the effect of different nozzle angles. The nozzle angle (θ) was measured from the horizontal ($\theta = 0^\circ$ being the case with the nozzle pointing horizontally downstream: $\theta = 180^\circ$ the case with the nozzle pointing horizontally upstream).

A large range of nozzle angles and water depths were studied and photographs of the jet paths were taken by injecting dye into the nozzle. The final arrangement recommended is shown in the photographs reproduced in Figure 8 for a range of water levels; the recommended angle being $\theta = 30^\circ$. At this angle the jet is injected just above the wake produced by the half buried pipe and the lower edge of the jet does not touch the river bottom until it has travelled 5 to 10ft. (prototype) downstream. At this distance the jet will be well diluted before it attaches to the river bed.

The general philosophy for the discharge system was to produce an arrangement which achieved the design

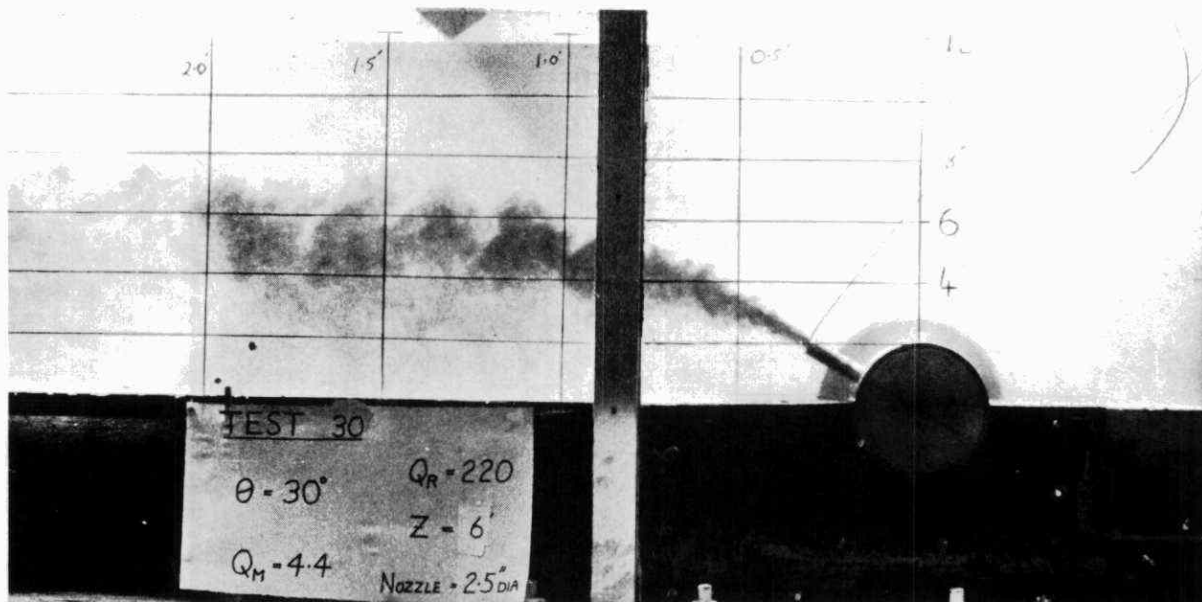


(A) Area ratio = 1.3

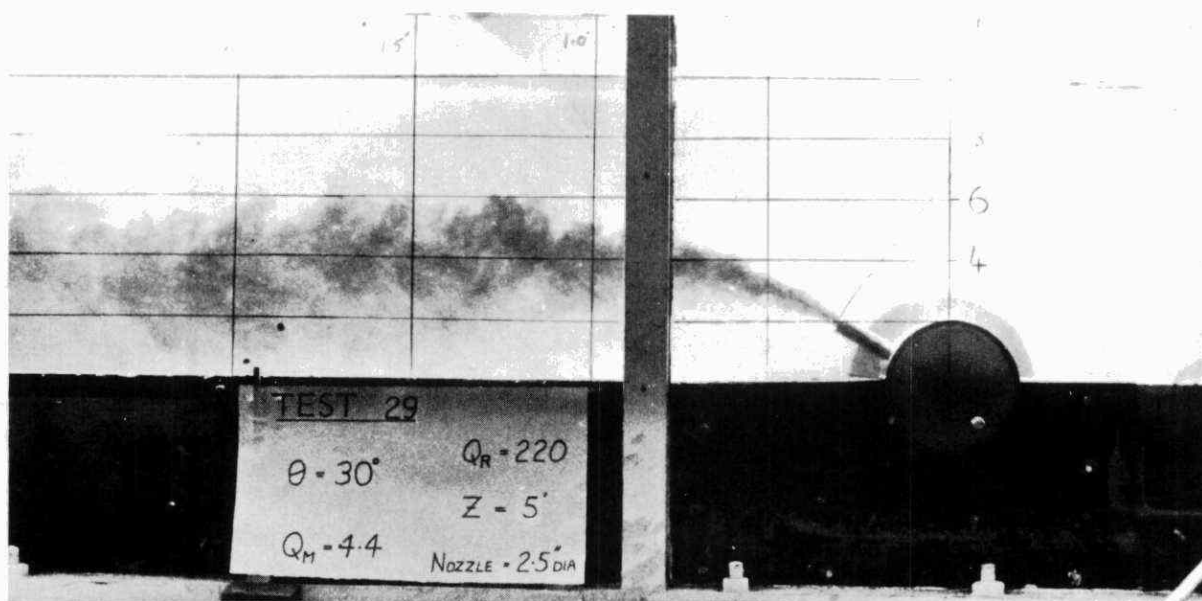


(B) Area ratio = 2.0

Fig. 7 Arrangement of Discharge Jets



Water depth = 6ft.



Water depth = 5ft.

Fig. 8 Recommended nozzles (2.5 in. dia. prototype) discharging at $\theta = 30^\circ$ into various river depths.

50:1 dilution in as short a distance from the manifold as possible. However, greater importance was attached to a method which would avoid any concentrations at the river surface higher than the final completely mixed condition; the object being to maintain a clear zone for the passage of migratory fish.

Experiments were undertaken in the 14ft. wide flume using the full span manifold and injecting a dilute salt solution. Four conductivity probes, arranged at different depths, were used to measure the salt concentration at various points downstream of the manifold. These results confirmed in general the pictorial representations derived from the sectional tests. One aspect that was emphasised by these tests was the random nature of the concentration at a given point in space, particularly very near the manifold. Variations of up to 100% from the mean were noted in the first 12ft. (prototype) from the manifold, and further downstream, say 30ft. where the mean concentration did not vary so much with distance, the fluctuations with time were of the order of 25%. This behaviour is, of course, a well documented feature of jets, but it is easily overlooked when studying mean values of dilution with distance.

The height of the diffuser supply tank is determined by the head required at maximum flow. From the experimental results, the total head required above river level is 7ft. at a maximum design flow through the diffuser of 10,000 USGPM.

Control of Dust Emissions from the Mine Site

Recognising the importance of controlling dust emissions from the processing operations and general work area, the Company has built into the mill design the most reliable and effective modern dust control procedures available, meeting internationally accepted standards. The principle applied to the design of dust collection systems has been one of containment of as much dust as possible, so that the air requirements are minimized. All ductwork from the pickup points in the crushing and screening area run vertically into plenums, enabling air quantities to be varied over a wide range without dust settling out in the duct work. If it is found possible to operate with smaller quantities of air, due to the effectiveness of the enclosures provided, considerably lower dust loadings will be experienced with consequent reduction in particulate emissions. Wet dust collectors are used throughout, with efficiencies better than 99.5% operating at approximately 15 inch water gauge pressure drop across the throat. Emissions are designed not to exceed 50 to 70 mg of solids per cubic metre of air in any of the exhaust discharges. Because of the lower density of the limestone material associated with the zinc and lead minerals, the constituents in the exhaust gases will contain much less zinc and lead minerals than the host material, as shown by tests on similar discharges in other Irish mines.

Ore Transport, Storage and Secondary Crushing

Overhead conveying systems for crushed ore transport are totally enclosed to prevent ore spillage on to roadways and to prevent fine dust blowing from the surface of the ore in transit. Primary crushed ore from underground is deposited in a covered ore storage building. The extracted exhaust gases from the building are passed through a high efficiency wet scrubber, rated at 10,000 cfm, to remove dust particles before discharging to the atmosphere.

Ore from the storage building is conveyed to the crushing and screening section of the mill building, where all the crushing and screening operations are provided with dust collection hoods and exhaust fan systems. Before discharging the exhaust gases to atmosphere, the dust is removed in high efficiency wet scrubbers rated at 60,000 cfm. Crushed ore is transferred to storage bins (with dust collectors of 10,000 cfm capacity) in the mill building.

Concentrator and Concentrates Storage

Each of the oil fired rotary driers is installed with exhaust fans and high efficiency wet scrubbers to remove dust particles from the moist air stream before discharge to atmosphere. The wet scrubbers on the zinc and lead driers have rated capacities of 40,000 cfm and 6,000 cfm respectively.

Zinc and lead concentrates from the driers are transferred to separate sections in the concentrates storage building by enclosed conveyors. Loading of concentrates into rail wagons takes place inside the concentrate storage building which is maintained at a negative pressure relative to the outside atmosphere by exhaust fans. Dust is removed from the exhaust gases in high efficiency wet scrubbers at rated capacities of 6,000 cfm for the lead storage section and 35,000 cfm for the zinc storage section. Operators in front-end loaders used in the storage section are protected in sealed air-conditioned cabs. Air quantities are sufficient to remove diesel fumes generated by the front-end loader engine.

Similar dust controls will be incorporated at the shipping installation on the Boyne estuary.

Noise and Vibration Control

Noise levels will be controlled to remain within limits conforming with internationally acceptable practice (ISO R 1996). These standards take into account the loudness as well as the duration of noise.

Noise Control Policy

Noise control has been carefully studied and strict control of operations is being exercised in the following respects:

- (a) Minimising the loudness of blasting, machinery and transportation;
- (b) Timing the occurrence of noise;
- (c) Siting the inevitable sources of noise;
- (d) Reducing the propagation of inevitable noise.

Noise Sources

Operational noise is predominantly due to the following sources:

- (a) Drilling and Blasting
- (b) Compressors and Pumps
- (c) Concentrator
- (d) Handling and moving of ore and rock
- (e) Fans
- (f) Transportation

(a) Drilling and Blasting

As evident from Table 9, noise from drilling and blasting was a problem during the preparatory stages, when some of these operations had to be carried out on or near the surface. Virtually all blasting and drilling is now below ground and neighbourhood noise from these sources is no longer significant.

TABLE 9

TYPICAL NOISE LEVELS NEAR KELLS ROAD

Period	Monthly number of blast incidents within noise range (dBA):		
	60-69	70-74	75-79
July 1973	12	3	2
August	33	3	2
September 1973	27	0	0

(b) Compressors and Pumps

The characteristic noise emanating from compressors and pumps can be very irritating. Moreover, since compressors and pumps usually operate in recurrent duty cycles, the re-starting of such machines after a brief pause tends to make this noise even more noticeable. The choice of compressors, the effectiveness of silencers, baffle chambers and the construction of the compressor house are of great importance in reducing neighbourhood noise from these sources.

For example, the original compressor house at the development shaft, containing 3 compressors with a capacity of 1000 cfm at 100 P.S.I. for each compressor, was a simple corrugated structure. The following sound pressure levels were measured outside residential properties at various distances from the compressor house.

Distance from Source	Noise Level
1000 feet	52dBA
2500 feet	46dBA

Following the installation of silencers, baffles, concrete block walls and sound proof doors, noise levels were reduced to an acceptable limit of 45dBA at the property boundary - 100 feet from the compressor house.

(c) Concentrator

Conditions imposed by the Planning Authority require noise levels to be kept within 45dBA at the property boundary. Typical noise levels for a conventional concentrator processing 7,500 tons of ore per day can be of the order of 65 to 70dBA at 300 feet distance, 55 to 60dBA at 1,000 feet distance and falling below 45dBA beyond some 3,000 feet. Consequently, the noise level at the site boundary nearest to the mill-house could approach 65dBA and occasionally exceed it. The subjective effect would be that of a noise four times as loud as the prescribed limit (i.e. subjectively, noise appears to be doubled for each measured increase of 10dBA). Special features are, therefore, incorporated in the concentrator design to bring about a substantial reduction of the noise emission.

In this context, it is interesting to note how much the design criteria are dependent on local conditions. In Canada, for instance, the design of a concentrator building is primarily determined by the need to provide thermal insulation. In the particular neighbourhood situation of the concentrator at Navan, the design of the walls and roof was governed by the need to provide adequate sound insulation. Double wall construction, with an inner wall resiliently mounted to the room side of the channel beams, and a substantial infill of fibreglass between the two walls, provides effective means for reducing emission of mill-house noise to within acceptable levels. This is of particular importance because the facility operates through the night.

(d) Handling and Moving Ore and Rock

A conveyor transfers ore from the shaft and decline to the processing plant. This is far less noisy than scoop trams, front end loaders or other diesel-engined vehicles. Moreover, the unavoidable impact noise of rock hitting the sides of trucks or storage bins when loading or unloading is also obviated by this means.

(f) Transportation

Large diesel engined vehicles are very noisy, typically reaching 90dBA at 25ft. distance and more if vehicle maintenance has been poor. With several such vehicles simultaneously operating, the noise at the site boundary can exceed the permissible limit, unless number, routing, maintenance and operation is adequately controlled. Diesel locomotives are also sources of appreciable noise. These problems are under constant surveillance to ensure that excessive noise is not propagated.

Control of Vibration

Vibrations due to mining operations are predominantly the result of blasting. In an underground mine a number of factors affect the magnitude of the vibrations registered on the surface. Amongst these are the depth at which the explosion takes place and the characteristics of the ground through which the vibrations must travel. These two factors cannot, of course, be altered but substantial controls can be exercised in other areas to minimise vibration levels.

The most important of these relate to the size and distribution of drill holes, the quantity and distribution of explosive placed in these holes and the time sequence of detonating a number of explosive charges.

By detonating the charges in quick succession rather than simultaneously, vibration levels are substantially reduced in a safe and convenient way. Other means of control are provided by relating the quantity of explosive used to the depth underground and to the time of day for which the detonation is scheduled; the use of centralised blasting and the use of maximum detonator numbers so as to minimise the amount of explosive used in each single shot.

With effective technical control it is possible to keep vibration levels below 0.3 in/sec (particle velocity) and this will guarantee the complete safety of residential and other buildings in the area.

AESTHETICS

Landscaping

While many of the possible conflicts between industry and environment may go unseen, the physical superimposition of a massive building complex on a rural landscape can create a startling impact.

Normally when industry and environment collide, it is the industry that must be altered to minimise the impact, but where that impact is visual, both must be modified. The building complex must be designed to minimise

the impact while yet being efficiently functional and the immediate landscape modified to absorb the buildings in a manner compatible with the landscape at large. Not only must the physical form be acceptable but building and structure colour must not dominate. The ability to apply trees and shrubs with immediate apparent effect must be available.

Tara's initial approach was analytical in a practical way. Plans and designs can be accelerated and produced at short notice but trees and shrubs take time to grow. The first approach to landscaping, when the development commenced, was the immediate establishment of a tree bank and nursery which now holds a combined stock of trees and shrubs of over 70,000.

The object of this exercise is to have immediately available the required quantities, species and sizes of plant material by the time building development permits landscaping to proceed.

Stage two of the exercise was the retention of Consultants who not only specialise in the construction of mineral processing plants, but who are also leaders in the design of aesthetically pleasing industrial structures.

Stage three is the landscape master plan, the objective of which is not only the integration of the buildings into the landscape but also into the surrounding non-industrial land.

It is Tara's intention to efficiently utilise all non-industrial land on the mine site. This will be managed intensively as a grassland/stockfarm unit and it will form part of the overall monitoring program. The end product will be an industrial complex, unique in design, integrated in a series of landscape features and farmland. It is thus hoped that the existing landscape, itself the product of an evolving land use pattern, will be enhanced by the development.

The landscape plan, however, is not based only on visual factors but takes into account the vital part that landscaping can play in the amelioration of the noise climate. While the greatest care is taken in equipment and building design to reduce industrial noise, the use of strategically placed and carefully designed earth mounds can contribute substantially to the reduction of noise levels.

Buildings

A number of architectural features of noteworthy interest have been incorporated into the project planning. The situation and orientation of the process and ancillary service buildings has been arranged to obtain a high degree of geometric symmetry. In particular, considerable care

has been taken to avoid the "criss-cross" effect of approaching and retreating conveyor galleries often associated with mine plant layouts. Where it has been necessary to vary building profile elevations because of internal headroom requirements, equipment has been arranged to restrict the number of changes and lean-to structures have been studiously avoided.

Certain remote process functions, usually confined within pre-engineered utility structures, are planned to be housed in custom-designed buildings. This is exemplified by the conical shaped coarse ore storage facility.

In general, buildings are clad in dark brown insulated metal siding. Cylindrical bins are painted straw colour and conveyor housings are blue. This colour scheme should harmonise with the lush green countryside of the summer and the yellows and browns of autumn and winter. The administration and laboratory complex tie in with the plan by using horizontally the same dark brown siding with continuous bands of heat reflecting grey glass.

PUBLIC RELATIONS/EDUCATION PROGRAM AND SOCIAL IMPACT ASSESSMENT

Public and Community Relations Programs and their Effects

In designing a program of environmental protection for such an area, a mining company, and indeed any other industrial or municipal developer, must take into account the total environment which, of course, includes the people living within its particular area of operation and influence. The protection of these people entails not only ensuring the quality of the air they breathe and the water they drink. It also demands that their understandable need for information be satisfied, that their doubts and misconceptions be dispelled and that, as far as possible, their legitimate grievances are satisfied.

This aspect of environmental protection cannot be undertaken on a haphazard basis. The public and community relations program must be planned just as carefully as the nature conservation program. If the community relations program cannot achieve satisfactory results then, to a considerable extent, the whole environmental effort has been wasted. Even though environmental protection policies may, in large part, be dictated by feelings of social responsibility within the individual company, their ultimate aim must be to protect people and to ensure that the people know they are being protected.

Navan presented a unique set of problems in this regard. As stated earlier, the mine, one of the largest of its kind in the world, is situated within a half a mile of a quite densely populated urban area, by Irish standards. Six thousand people live practically within sight of the production shaft head frame. Every move by the Company is

carefully watched and noted. Without doubt, justice, or more importantly injustice, will be seen to be done. From a purely practical viewpoint, if the Company were to face a total opposition of the indigenous population, operations could not continue and the development of the project could be seriously and expensively impeded.

With these considerations in mind, the Company set about providing the people of Navan with a comprehensive information service, on environmental protection and the general details of the development. An information office was opened very soon after the discovery of the orebody and its existence was widely advertised. This office is staffed by Company personnel capable of answering questions on all aspects of the development, of assessing complaints, and, if necessary, of making retribution for any injustices. Company personnel adopt an open policy on addressing public meetings and the many invitations received are accepted and entered into enthusiastically.

Information is supplied to the local Press on a consistent basis. The Company participates in local trade fairs and careers exhibitions and has issued publications on mining in general and on its own operations and environmental program in particular. A great deal of attention is paid to schools and school children are encouraged to avail of the Company's information services.

Close contact is maintained with groups having a particular interest in the development and where relevant their advice and views are sought. Such groups include An Taisce - a National environmental watchdog body with certain statutory powers, farming associations and fishing clubs. In addition, a close liaison is maintained with Government Departments and Government sponsored agencies.

The Company participates, though not extravagantly, in a number of local and national sponsorships and, in as far as is possible, its personnel have become involved in the social and business life of the town. Tara's public information structure stresses the economic value of a mining industry to a town like Navan. This is not a simple task. Navan town was already highly industrialised before Tara's arrival and unemployment was not a problem of any magnitude. Consequently, the local population is not likely to be over impressed by the promise of a major new source of employment.

Promises of enhanced prosperity alone are not likely to satisfy genuine fears of the environmental consequences of the project. However, the fact that miners in Ireland receive significantly higher wages than the average worker in other industry is not without significance, especially when allied to the Company's local purchasing power and to the possibility of the establishment of peripheral industries in the area.

One of the major obstacles to be overcome in Ireland is the fact that the mining industry is almost completely new and hence unfamiliar to most Irish people. In general, they tend to associate it with coal mining in Britain and the tendency to accept the worst aspects is noticeable. In addition, there is the normal human reaction of being afraid, not necessarily of what is actually harmful, but more of what is different. This was particularly obvious in the case of local reaction to the noise from blasting operations in the early stages of the project, although noise level measurements taken by the Company showed that for every thirty noise occurrences due to blasting there were forty-eight thousand occurrences of similar or greater intensity originating from indigenous non-mining sources.

This can be applied to many aspects of the development. People tend to be afraid and uncertain about the unusual and to most people in the Navan area mining is a completely unusual industry and has many unknown factors. One aim of the public relations program was, therefore, to make the local people familiar with the mining industry by making clear to them the reasons for each particular course of action or policy decision by the Company. This, it was felt would also tend to create a sense of involvement. That Navan possessed the largest zinc/lead mine in Europe and one of the largest mines of its kind in the world had to become a source of pride to local people.

Opinion Survey

To assess the effectiveness of the environmental and community relations programs, an opinion survey was undertaken recently for Tara Mines. Preliminary findings are very encouraging if taken as a measure of the overall success of the programs. They show that the vast majority of the Navan population expects that the town will do far better than the rest of the country in the next ten years. Nine out of every ten people feel that mining is good for the country as a whole and 69% of all people interviewed were pleased about the existence of a mining company in the Navan area. They invariably recognised that the value of their property would appreciate much faster because of the existence of the mine.

A large majority anticipated and welcomed the prospects of higher than average earnings among mine workers. Almost half the men under the age of forty-four expressed some interest in working for Tara and over a quarter were very interested. Again a large majority of people appreciated that there was a big difference between coal-mining and the type of mining planned for Navan and understood that hard rock mining was preferable to coal mining. About 64% of all the people interviewed felt that Tara was taking adequate steps to protect the environment. Of the remainder, 27% were in the "don't know" category, which underlines the difficulty of total exposure even by an intensive information program within a small area.

INDUSTRIAL PLANNING IN IRELAND

Government Control of Industrial Development in Ireland

The principal act governing industrial development in Ireland is the Local Government (Planning and Development) Act, 1963. This act, which is in the process of revision, prescribes that each planning authority must prepare a development plan which must include objectives for preserving, improving and extending amenities in its area. These objectives may provide for prohibiting, regulating or controlling the deposit or disposal of waste material and refuse, the disposal of sewage and the pollution of rivers, lakes, ponds and the seashore.

Permission may be refused for development which conflicts with the proper planning and development of the area, having regard for the provisions of the plan. The authority, when granting a planning permission, may attach conditions relating to the discharge of effluents from any proposed premises.

Effluent discharges to fishery waters may be licenced under the Fisheries Act (1950). In granting a licence, the Minister has no statutory quantitative guidelines on which to base his decision. The only available guidelines are in the form of draft standards (Institute of Industrial Research and Standards(1970)).

Under common law, every riparian owner and every owner of a fishery has a right to have a stream come to him in its natural state in flow, quantity and quality and any interference with that right may be restrained by injunction.

Aerial emissions are controlled in the case of "Scheduled Works" under the Alkali etc. Works Regulations Act 1906. This Act has been recently amended but, to date, does not control aerial emissions from mining operations. These controls are usually incorporated in the conditions imposed by the planning authorities under the 1963 Planning Act.

The lack of definitive environmental control guidelines in the current legislation added to the difficulties of the design engineers in planning this development. The criteria adopted were based on an extensive review of current pollution control practices in the U.K., U.S.A., Canada and Europe. Furthermore, the design anticipates comprehensive environmental legislation now being drafted by E.E.C. authorities.

The Irish Planning Act

The procedure under the Planning Act is as follows:

A developer submits a planning application to the local authority and the plan is available for public scrutiny. Every citizen or citizen body has the right to lodge objection on specified grounds, within a statutory period. The local authority may grant planning permission, in full, planning permission with restrictions, or even refuse planning permission.

If there are objections to the development an enquiry is held by the Department of Local Government. This enquiry may be by correspondence or public hearing and the applicant must satisfy the appointed Government Inspector that each objection is groundless or face an amending condition or even rejection of his application. The entire planning procedure, from application to final ratification, may take a year.

The Tara Mines Planning Permission

In the case of the Navan development, planning conditions were imposed by the Meath County Council relating to: control of water, gaseous, dust and noise emissions, landscaping plans and final rehabilitation. These were subsequently altered as a result of third party objections at a public enquiry. The following are some of the specific conditions applied:

- (a) Landscaping shall include the planting of trees, hedges and shrubs, the forming of mounds or hollows in the earth and generally managing the land and vegetation to improve the appearance of the site and to mitigate the visual and aural impact of the industrial nature of the development on the locality. In particular, groups of trees shall be planted around the tailing pond boundaries.
- (b) The specifications shall provide that ventilation raises shall be relocated as far as is practicable from any residence or public road and that their fans shall be placed near the bottom of their shafts.
- (c) The development shall be operated in such a manner that no matter deleterious to public health, fish life, livestock or amenity will be discharged into any river.

Effluent from the development shall comply with the standards and limits set out in I.I.R.S.* (1970), except as otherwise provided in these conditions. All effluents shall be treated in sedimentation and aeration ponds before discharge and shall be treated to a standard which will ensure that the river water at any monitoring point located not less than fifty feet downstream of the point of discharge will not have values for the following metals in excess of the following limiting concentrations:

*Institute for Industrial Research & Standards.

Lead	not more than 0.05 milligrams per litre
Chromium	not more than 0.05 milligrams per litre
Cadmium	not more than 0.01 milligrams per litre
Copper	not more than 0.1 milligrams per litre
Zinc	not more than 0.5 milligrams per litre
Arsenic	not more than 0.01 milligrams per litre
Antimony	not more than 0.01 milligrams per litre

The river water at any monitoring point located not less than fifty feet downstream of the point of discharge shall be such that the sum of the ratios of the actual concentration of each metal in the water to the concentration stated below for fish life of that metal shall at all times be less than unity, the said stated concentrations being:

Lead	1.0 milligrams per litre
Chromium	1.0 milligrams per litre
Cadmium	0.01 milligrams per litre
Copper	0.1 milligrams per litre
Zinc	1.0 milligrams per litre
Arsenic	0.01 milligrams per litre
Antimony	0.01 milligrams per litre

- (d) Effluent prior to discharge shall comply with the following limiting standards:

Lead	not more than 0.2 milligrams per litre
Cyanide	not more than 0.1 milligrams per litre
Iron (filter-able)	not more than 1.0 milligrams per litre

pH levels shall not be less than 7 or more than 9.20 parts per million five day biological oxygen demand and 30 parts per million suspended solids.

No mercury shall be discharged to a river so as to increase the concentrations of mercury existing in that river.

The rate of discharge of effluent to a river shall not exceed 8,700 gallons in any minute or $2\frac{1}{2}$ million gallons in any 24-hour period.

- (e) Wells providing water for human or animal consumption in the vicinity of the site shall be sampled and analysed chemically once every quarter and the Developers shall bear not less than two-thirds of the cost of such special samplings and analyses. The results of all such analyses shall be made available to the planning authority as soon as practicable.
- (f) The development shall be operated in such a manner that atmospheric pollution from smoke, dust, grit, noxious offensive gases, or mineral particles shall be kept at such levels as to not be injurious to public health, livestock, vegetation or to amenity.

- (g) The emission from the dust collecting equipment shall not exceed 70 milligrams of dust or 23 milligrams of lead per cubic metre of air measured at a pressure of 30 inches of mercury and a temperature of 60 degrees fahrenheit.
- (h) The discharge of sulphur dioxide shall not exceed 200 lbs. per hour from a stack not less than ninety feet high.
- (i) Noise levels caused by mining and surface operations measured at any residence outside the site boundary shall not be greater than those specified by I.S.O. (1971)*

The maximum noise caused by blasting measured at any residence shall not be greater than 75dBA between 8a.m. and 8p.m. and 65dBA between 8p.m. and 8a.m.

Vibration resulting from blasting measured at any residence at any time shall not be greater than 0.3 inches per second peak particle velocity.

- (j) The Developers shall monitor continuously all noise and vibration at not less than three points near the boundary of the site between the Blackwater and the Knockumber Road.
- (k) If and when the mine becomes disused, and has, in the opinion of the planning authority, permanently ceased to function as a mine, the Developers shall, to the extent required by the planning authority, take down and remove all or specified plant, equipment and installations, buildings and stored material and shall reinstate the site above and below ground visually and hydrologically (so as to ensure a natural self-regulating terrain) to a condition fit for agricultural use or for such other use or uses for which planning permission may be granted.
- (l) The Developers, before commencing any part of the development, shall either deposit with the planning authority a sum of two hundred thousand pounds (£200,000) or shall enter into a covenant with the planning authority to pay annually to the said authority a sum equivalent to ten thousand (£10,000) at the monetary value pertaining on the date of first payment and continue such payments until the mine permanently ceases to function as a mine. The first payment to be made on 31st December 1975, or on the last day of the month in which production of ore concentrate commences, whichever is the earlier.
- (m) The capital sums and accrued interest derived or any portion thereof shall be available to the planning authority and may be used by them for the purpose

*International Organization for Standardization.

of securing the satisfactory carrying out and completion of the reinstatement of the site or shall be refunded to the Developers in the event of the planning authority being satisfied that the reinstatement work has otherwise been satisfactorily completed in accordance with the provisions of 21 (a).

ENVIRONMENTAL MONITORING AND CONTROL FOR THE FUTURE

The installation of environmental safeguards alone is not enough to guarantee the protection of the environment and a constant surveillance of every aspect of the development is vital. A comprehensive environmental monitoring program has been devised for the life of the mine which provides for the regular monitoring of water and atmospheric quality, sound and vibration levels, as well as heavy metals in herbage, soil and stock. These regular surveys will ensure that the mine constantly meets the strict environmental standards which the Company aims to achieve.

River and Water Quality Monitoring

A recording river flow gauge will be installed in the Boyne downstream of the point of abstraction. The information thus gained, together with the data gained from monitoring the clearwater pond overflow, will be used to determine the water discharge rate in order that the required water quality standards in the Boyne can be met.

River Chemistry Water Sampling and Chemical Analysis

The monthly water quality survey at the seven stations on the Boyne, Blackwater and Yellow Rivers will be continued throughout the life of the mine. However, it is also proposed to install automatic water samplers on the Boyne above and below the abstraction point and on the discharge from the clearwater pond, to collect 24 hour composite water samples for regular chemical analyses for suspended solids, B.O.D., heavy metals and cyanide. An extension of the monthly analyses already being carried out will provide data on cadmium, arsenic, antimony and mercury levels required to satisfy the planning authority's prescribed heavy metal discharge limits.

Other water samples will be collected regularly from the various ponds and water circuits in the mine site for chemical analysis. This internal monitoring will be used to ensure the continued high level of plant performance and the highest practicable standards of water quality.

Biological Monitoring

As an extension of the baseline biological monitoring program, late summer benthic fauna surveys will be undertaken in:

- (a) the Boyne River in the area of discharge
- (b) in the Blackwater River adjacent to the mine site, and
- (c) in the Yellow River over the area which could be influenced by the tailings pond.

These surveys will be supplemented by early spring surveys to evaluate the seasonal population variation.

The electro-fishing program, on the Boyne and Blackwater rivers, will establish species, age and biomass for the fisheries, and, on the Yellow River, it will evaluate the importance of this stream as a spawning area. Further useful information will also be acquired from data obtained from the migratory fish passes on the Boyne and from commercial and rod catches.

Well Water Survey

A large number of local residents obtain their domestic water supplies from wells and most farmers are similarly dependent for farm water supplies. Consequently, apart from monitoring the physical effect of the underground mine on well water supplies, the water quality will also be regularly monitored.

Internal Monitoring of Dust Levels

In conjunction with comprehensive medical surveillance of mill and mine personnel, regular monitoring of dust levels will ensure conformity with recommendations for factory atmosphere.

All external exhaust gas ducts are provided with suitable sampling ports for regular monitoring of dust concentrations. The results of these tests will be compared with consent limits for dust emissions from this operation to ensure that the dust control procedures in the mill meet the required standards.

External Monitoring of Dust Deposition Rates

As an additional check on the dust emissions, eight standard dust deposit gauges will be installed around the periphery of the mine site together with six extra gauges at a radius of about one mile. Another four gauges will be installed around the tailings pond to check that no abnormal circumstances arise.

The directional dust gauges around the mine site and the tailings pond have been positioned so that the dust contributions from the mining operations can be distinguished from the background deposits. Each of these gauges collects four separate deposits over a monthly period.

The monthly samples of dust deposits in each gauge will be analysed to determine the total deposit and the lead and zinc content of the residue. Spot checks will be made for cadmium, copper and arsenic in the dust samples. In addition, short term (i.e. 8-24 hour) samples will be taken using a high volume dust sampler.

Monitoring of smoke and sulphur dioxide levels will continue until a complete pattern of levels is compiled. These measurements will provide a baseline for comparison during the life of the mine.

Soil, Herbage and Stock Surveys

As well as dust monitoring, soil samples will be collected from selected sites around the mine, the tailings pond and the rail line to Drogheda on a once yearly basis. The samples will be analysed for zinc and lead. Representative samples of herbage will be collected from the same sites quarterly. These samples will be analysed for zinc and lead. The techniques used for the sampling and analysis of soils and herbage will follow the procedures employed by An Foras Taluntais in the baseline surveys.

Agricultural stock in the region will be surveyed regularly to assess important bio-chemical parameters in blood and liver tissue and mineral metabolism. The results of the survey will be correlated with data from the herbage sampling as well as the results of the pre-mining stock survey.

In order to ensure control of stock monitoring the company proposes to develop its own farming program, utilizing non-industrial land in strategically situated areas. Four separate farm units will be established. The livestock selected for these units will form the basis of a single-suckler herd of Hereford cows and a small nucleus of breeding mares.

The health of the animals on these units will be under regular and close veterinary supervision and any indication of abnormality or failure to thrive subjected to the closest scrutiny. All casualties will be given detailed post-mortem examinations and livers, kidneys and gastro-intestinal contents submitted for chemical analysis for zinc and lead. To ensure adequate health and performance, all cattle will be weighed once monthly. Blood sampling to ensure normal haematological and biochemical patterns, will be carried out on 20 cattle from each unit twice yearly with similar haematological studies performed on all mares and foals. Faecal analysis for parasites will be performed where indicated.

Quarterly blood samples, half yearly milk samples and liver biopsy will be taken from representative cows in the herds. Blood from all horses and cows will

be analysed for zinc and lead. Samples of liver and kidney from all cattle sent for normal slaughter will be similarly analysed. A survey will be carried out, with the co-operation of a local knackery, to monitor zinc and lead residues in casualties in the locality and a similar survey will be carried out in an area removed from the mine. In addition to Tara's own animals, it may be desirable, from time to time, to monitor other animals on selected properties in the vicinity of suspected trouble spots.

Noise and Vibration Monitoring

Mining, mineral processing and transportation inevitably cause noise. However, if the noise produced is kept under strict surveillance and control, undue impairment of the noise climate in the environment of the mine can be avoided.

While continuous monitoring of aircraft or road traffic noise is no longer uncommon, the requirement for continuous noise and vibration monitoring, imposed as a condition of planning consent, is probably unique. It created a need for the design of a custom-built system, because noise produced by mining and mineral processing is different from traffic noise in character and in statistical distribution over space and time, and standard traffic monitoring systems are therefore not ideal for monitoring a mining site. The system adopted takes care of the special requirements for management information, as well as for comprehensive historical information to be collected, processed, logged and printed out and for alerting functions enabling noise and vibration levels to be controlled within acceptable limits.

System Configuration

To achieve adequate coverage of the mine site activities, three noise and three vibration monitors are located in strategically chosen positions around the boundary. Omni-directional microphones are used to obtain a panoramic interpretation of the noise climate. Three separate transducers are located at each of the three vibration monitoring points. These individually measure the vertical and two orthogonal horizontal components, and permit an accurate computation of the maximum resultant peak particle velocity as well as the vertical and horizontal maxima. This is of importance because human sensitivity to vibration, and therefore nuisance, depends on the vertical component, whereas potential damage largely depends on the horizontal component of the vibration pattern.

The six continuous noise and vibration monitors produce a very substantial amount of information which must be suitably processed and recorded. This necessitates the integration of the monitoring facilities with a comprehensive data processing and logging system.

Outputs from the remote transducers are conveyed by cable to the central data processing facility.

To give a comprehensive picture of the noise environment, three parameters, viz. (a) the mean energy content of each noise signal, (b) the maximum noise level rate and (c) the background noise level, are computed and recorded for each ten minute interval. These data are reduced on line giving a four hourly print out to serve as management information. For each of the vibration channels the peak particle velocity is recorded in each blasting period in such detail that each individual blast can be identified.

System Design Considerations

Graphic noise level recordings provide an interesting and instructive representation of ambient noise. However, more sophisticated methods will be used for data presentation for legal and management purposes, for long term records and for analysis by electronic data processing.

The following requirements have to be met:

1. Comprehensive permanent records of noise and vibration from site activity;
2. Substantially automatic operation; minimising labour usage for operation, equipment supervision and data handling;
3. Sufficient noise pick-up points to ensure adequate coverage of noise sources;
4. Automatic data processing to show significant parameters on an hourly or daily basis for noise, and on a daily basis relating to blasting schedules for vibration.

The most advanced weatherproof precision microphones are used. These, as well as the vibration transducers, are capable of remotely operated calibration which is part of the automatic self-checking facility built into the monitoring system.

The data are recorded on magnetic tape for long-term filing and comprehensive data processing if and when required, and also to compute on-line and print data suitably processed to serve as management information.

Information outputs are compared against present levels (which are different for different parts of the day and night) and warning signals are initiated when the present levels are exceeded.

The system is highly automated and incorporates a sophisticated automatic calibration and checking routine to ensure that reliable data is being recorded at all times, for both vibration and noise.

Monitoring at the Export Terminal

While all necessary precautions will be taken to eliminate the possibility of pollution from the terminal, a comprehensive monitoring program will examine estuary water and mud as well as mussels from the adjacent fishery.

CONCLUSION

While there is no statutory obligation in Ireland to produce an Environmental Impact Statement (E.I.S.) of the format recently adopted in North America, a basically similar approach was independently evolved by the company in the planning and development of this project. Such an approach is essential to provide a systematic method of incorporating environmental control limitations at the process design stage and to provide environmental baseline data.

Adherence to the standards which the company has established will require constant vigilance and will demand an ongoing commitment - both financial and ideological.

In designing a program of environmental protection for an area such as Navan a mining company, and indeed any other industrial or municipal developer, must take into account the total (natural and social) environment which, of course, includes the people living within its particular area of operation and influence.

The experience gained during the development of this mine clearly shows that the public and community relations program must be planned just as carefully as the nature conservation program.

Whilst all environmental components are important, the lesson of Navan clearly shows that the most important is people. Any change takes place in their presence and must have their approval.

(The author wishes to acknowledge the substantial contribution to this paper of Dr. R. Batstone of Cremer & Warner, Mr. W.G. Dallas, Conservation Manager, Tara Mines Ltd., and Mr. D. Holden of Michael O'Reilly Associates International Ltd.)

BIBLIOGRAPHY

- British Standard 1747: Part 1: (1969) "Methods for the measurement of Air Pollution - Deposit Gauges".
- British Standard 1747: Part 2: (1969) "Methods for the measurement of Air Pollution - Determination of concentration of Suspended Matter".
- British Standard 1747: Part 3: (1969) "Methods for the measurement of Air Pollution - Determination of Sulphur Dioxide".
- British Standard 1747: Part 5: (1972) "Methods for the measurement of Air Pollution - Directional Dust Gauges".
- Institute for Industrial Research and Standards, (1970), "Draft of Recommendation for the Disposal of Industrial Effluents" Ireland. SR5: 1970.
- ISO Recommendation R 1996: Acoustics "Assessment of Noise with respect to Community Response". International Organization for Standardization, ref. no. ISO/R 1996-1974 (E).
- Jeffrey D.W., Maybury M., Levinge I., "Ecological approach to mining waste revegetation". Symposium on minerals and the environment. Institute of mining and metallurgy. Report No. RR1283. London 1974.
- Lloyd, R., (1972), "Problems in determining water quality criteria for fresh water fisheries". Proc. R. Soc. London, Series B, 180, 439-449.
- Montgomery, H.A.C., and Hart, I.C., (1974) "Design of sampling programmes for rivers and effluents", Water Pollution Control Journal, 73, (1), 77-101.
- Prosser, M.J., (1974) "Plant discharge to the River Boyne - The hydraulic design of the manifold and piping system". British Hydromechanics Research Association Report. No. RR1238, Cranfield, England.
- World Health Organization, (1971), "International Standards for Drinking Water", W.H.O., Geneva.



"The Recovery and Treatment of
Spent Rolling Solutions at
The Steel Company of Canada, Ltd.,
Hilton Works Operation"

BY

A. A. Schuldt, Senior Utilities Engineer

and

V. A. Suffoletta, Assistant Utilities
Engineer.

A. A. SCHULDT

In recent years, the discharge of oil or fats into water courses has come under careful scrutiny. As a result of various industrial process waste surveys, some of which were conducted by the Ministry of the Environment, the Steel Company of Canada embodied within its negotiated water quality program, the necessary facilities to safeguard against potential oil contamination of process water. A particular vexing problem which was identified was the waste effluent from the Cold Rolling Mills. These discharges contain a combination of rolling and lubricating oils.

Rolling solutions are required to permit the cold rolling of carbon steel with modern high speed mills. In the formulation of these solutions, various types of tallows and mineral oils are blended to form an oil-water emulsion. These emulsions are tailored for specific applications by adding proprietary stabilizing agents. The agents give the

rolling solution specific lubricating and pressure bearing properties. These solutions, which have a finite service life, become contaminated with metal soaps and iron fines. Ultimately, the degraded mixture must be replaced with fresh solutions.

Treatment of spent solutions is essential before discharging the waste water, together with large quantities of cooling water, to the industrial sewer. In the late sixties some of the solutions, along with hydraulic fluid and equipment lubricating greases, were collected in clarifiers at the Cold Mill Basement complex. The fatty oils were allowed to solidify in the clarifiers. The solids were skimmed and collected for disposal. The major portion of the spent water containing some residual oil was then discharged to the industrial sewer and further settled and skimmed in a terminal lagoon system. The method provided partial oil recovery but the degree of treatment was insufficient to meet the requirements of the water quality control program. In order to meet the goals of the program the existing treatment method had to be upgraded.

Therefore, the available technology for treating waste rolling solutions was studied again and the existing facility for oil reclamation was reviewed in detail. Laboratory results conducted on Stelco's spent solutions revealed the following observations:--

- (a) The oil-water emulsions could be separated with chemical treatment using ferric iron and pH control.
- (b) The chemical requirements to achieve the separation depended on the oil concentration.
- (c) It was found to be uneconomical to upgrade the existing purification system to obtain adequate treatment in terms of flow and water quality.

It was, therefore, decided that in order to achieve adequate effluent treatment, the facility would have to be located in an area remote from the source. This would allow the selection of a system which could

handle the waste flows from all the cold rolling mills, as well as waste oily-water solutions which are generated by other steel finishing operations from the Steel Company of Canada, Limited.

With this fundamental knowledge, several processes were reviewed. Subsequently, a patented system was selected. The advantages of selecting this process were:-

- (1) The process was being used by other steel producers for the purpose of recovering fatty oils which solidified on standing.
- (2) Economically, the operating costs are minimized since part of the chemical treatment system uses a by-product from the Oil Recovery System itself.
- (3) The process would produce a recovered oil which could be used as fuel and generate a minimal amount of solid waste for disposal.
- (4) The technology of chemically treating oil-water emulsions was available and had been used in part, in other steel plants.

Basically, the process consists of two separate systems. One stage recovers solidified oils and the other stage treats the oily water emulsions. The oily water treating system is completely spared to ensure continuous treatment and permit routine and emergency maintenance. The plant has been in operation since April 1972. The facility has been treating all contaminated process water from various cold rolling operations at Hilton Works. In addition, waste oil products from a number of steel finishing operations are also treated to recover a useful fuel oil. In this sense, the completion of the centralized Oil Recovery System represents a major effort and partial fulfillment of an extensive water quality control program.

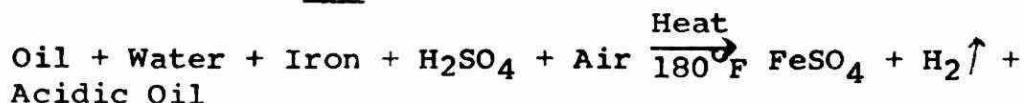
Although similar facilities are being used by other steel producers, a number of expensive modifications were required in order to obtain consistent plant performance. The facility in our opinion, represented the best known technology for

the treatment of lubricating solution as used at The Steel Company of Canada, Limited. To date, because of the experiences gained in attempting to meet governmental regulations, an improved version of this process would be available.

The Oil Recovery System can probably be effectively described with a series of process flow diagrams which cover the two main treatment stages namely the batch treatment of the solidified oils and the continuous treatment of oil-water emulsions. The continuous treatment stage is a duplicated system where each line is capable of treating 1500 U.S. gallons per minute of waste water.

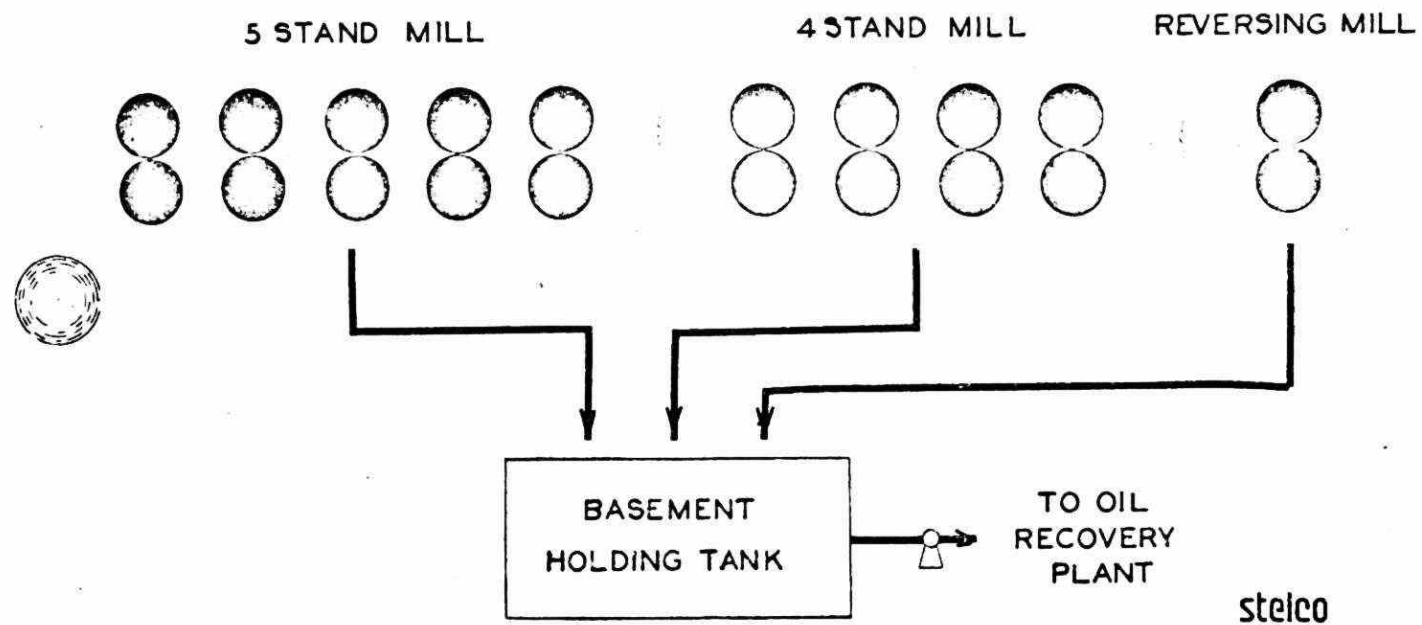
First, the Batch Treatment of Solidified Oils, Slide I. The spent process water containing various rolling solutions are collected from all rolling mills and are piped to the Oil Recovery Plant. The spent water is admitted to one of two 50,000 U.S. gallon surge receivers. Slide II. In the surge receivers, the initial oil-water separation occurs and some solidified oil will float to the surface. The solidified oils or fats are then refined in the batch stage of the plant. The weak solutions of emulsified oil-water mixtures are pumped continuously to the emulsion treatment stage.

In detail, the treatment of the solidified scum is as follows. The floating material is pumped to the scum tank by periodically draining one of the surge receivers. The water level is lowered. The scum is then heated with steam to liquefy the material. The material can then be pumped to the primary oil refiner. The treatment consists of mixing concentrated sulphuric acid with the scum, heating the mixture with steam and air agitating the batch. The reaction which occurs can be represented in the following manner. Slide III.

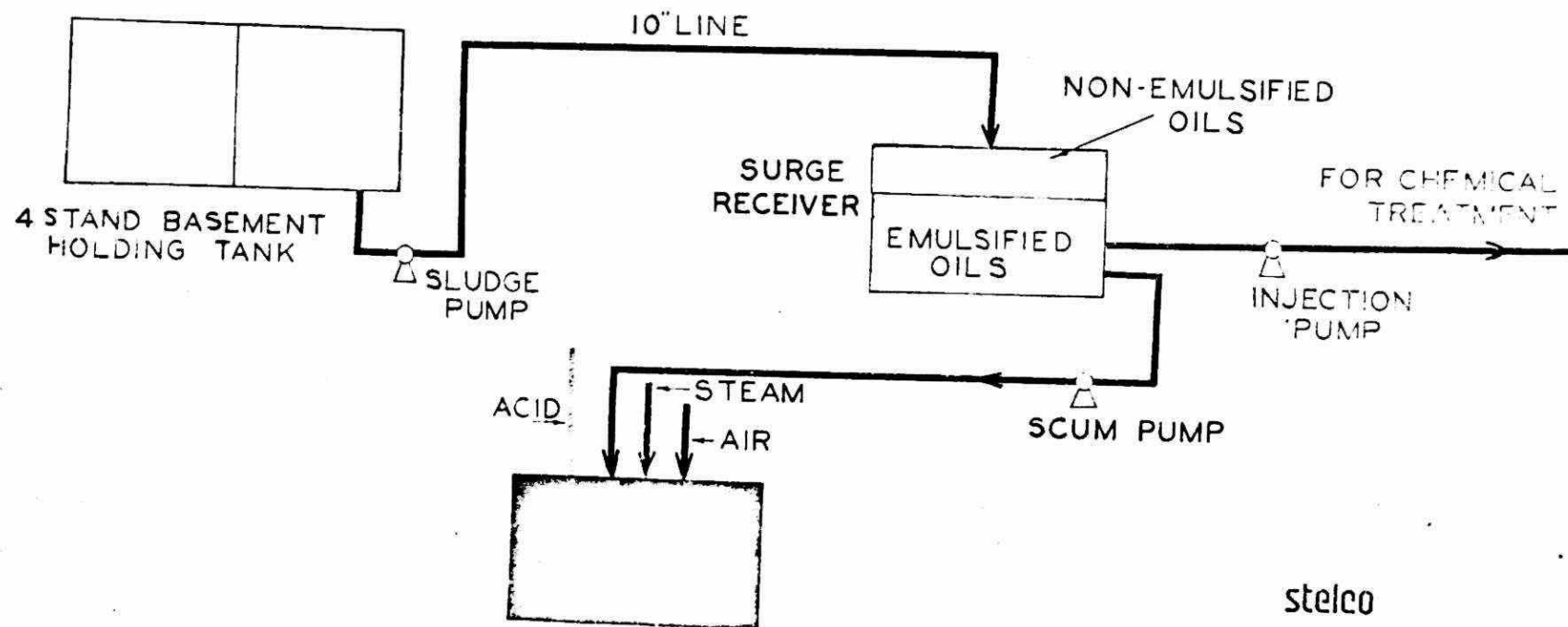


The purpose of the acid treatment is to dissolve the metal soaps. The resultant mixture is allowed to settle and yields two layers. Slide IV The aqueous liquid phase containing the iron salt solution is on the bottom and the acidic oil phase

COLD MILL COLLECTION SYSTEM

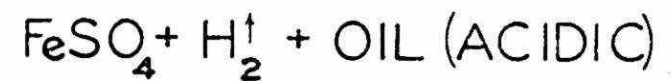


Slide I



Slide II

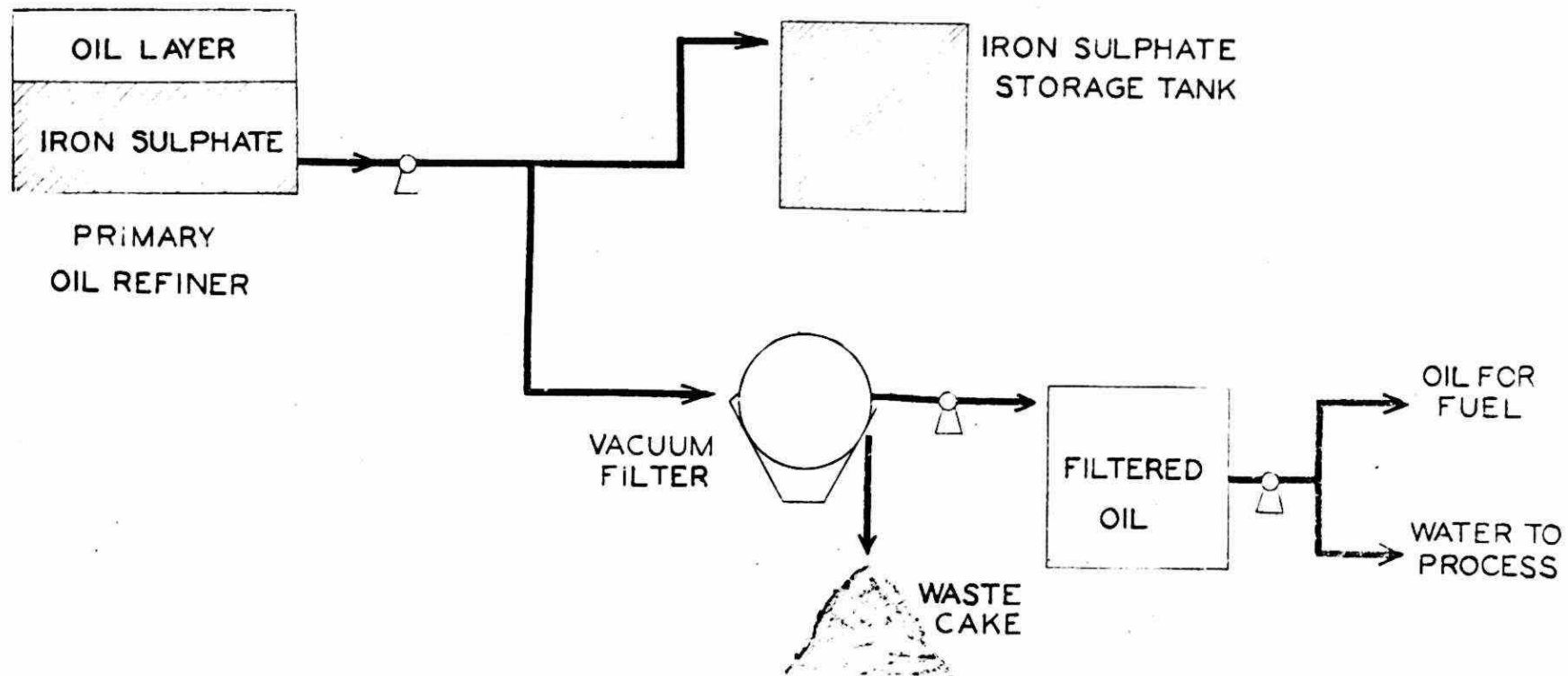
OIL PURIFICATION



stelco

Slide III

PRIMARY OIL RECOVERY



stelco

Slide IV

is on the top. The iron solution is pumped to a plastic storage tank to be recycled as one of the chemicals for treating waste water. Alternatively, any excess iron sulphate solution can be neutralized with lime and filtered to remove the solids.

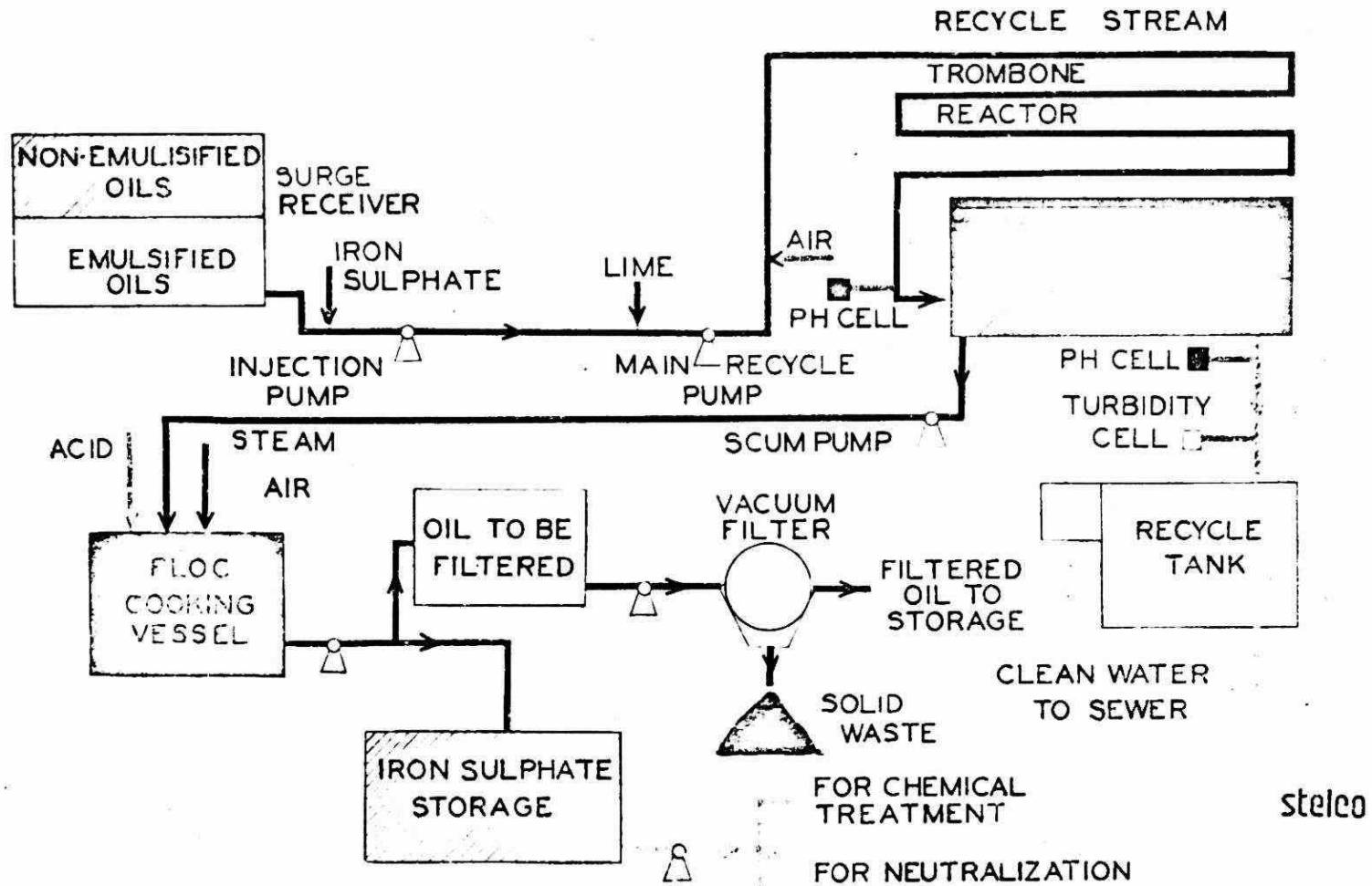
The acidic oils are then pumped to a rotary vacuum filter and filtered at a temperature of 180°F. Filtration removes inert grit and the filtering action improves the separation of the oil from the water phase. The acidic oil then is water washed at 180°F to remove the residual acidity. After several hours of standing, the water which has percolated through the oil, is decanted. A choice can be made to blend the water with the concentrated iron sulphate solution for future use or it can be returned directly to the oil-water treatment system for reprocessing.

Clean and relatively dry oil can then be stored or shipped as fuel for internal consumption. The batch operation recovers about 15,000 to 25,000 U.S. gallons of oil per month.

The second stage deals with the Continuous Treatment of Oil-Water Emulsions and is represented in Slide V. The oily water emulsions are chemically treated by forming a slightly cationic iron hydroxide floc which combines with the remaining oil in the spent rolling solutions. The emulsions in this case are normally slightly anionic.

The emulsified oily water, having concentrations of oil ranging from 100 to 2,000 ppm are automatically withdrawn from the surge receivers at preset rates by the waste injection pumps. The waste injection pumps discharge directly into the suction line of the main water pumps. The main water pumps have a common suction connection from the injection pumps and from a treated clean water sump tank. The preferential flow will be from the injection pumps. The purpose of the pumping arrangement is to ensure that a constant flow of water is pumped to the clarifier, regardless of the quantity of raw water which is available for treatment. In this manner, fluctuations in flows are stabilized. Furthermore, the technique reduces the possibility of having to treat highly concentrated mixtures.

WATER TREATMENT — PHASE I

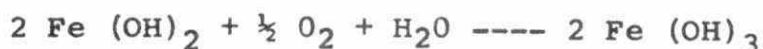


Slide V

At this juncture, chemicals are added to break the oil-water emulsion. A 0.5% iron sulphate solution is injected into the suction of the main water pumps. Lime is added to control the pH of the mixture and the total blend is pumped to the trombone reactor. The following reactions take place. Slide VI.



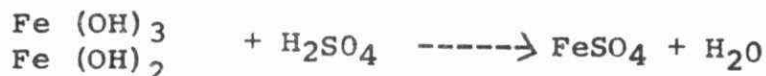
As soon as the chemicals come together, an iron hydroxide floc is formed and is further developed in the trombone reactor. The finely dispersed floc entraps the oil particles. Also at this point, sufficient air is added for complete air dissolving and to foster the oxidation of the iron floc.



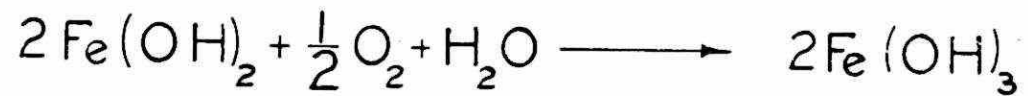
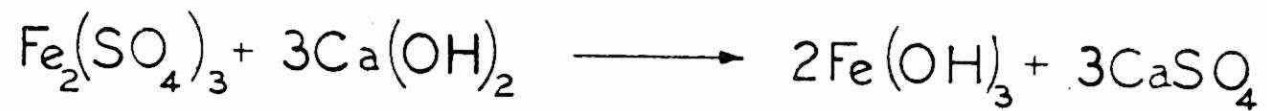
The addition rates of chemicals are automatically controlled on the basis of flow and the pH of the water.

SLIDE V The reacted water mixture is piped under pressure to a skimming vessel having a volume capacity of 50,000 U.S. gallons. As the water enters the skimmer, the pressure is released. The dissolved air evolves from the solution as extremely fine bubbles which attach themselves to the oil bearing floc. The floating floc is removed from the surface with the counter-current skimmers and is then collected in the scum trough.

The floc scum is pumped directly to one of the floc reduction tanks and held for treatment. The treated water is discharged from the skimmer through a baffle-weir arrangement to the clean water sump and then overflows to a sewer. The treatment of the floc scum is similar to the treatment of the concentrated oils. The scum is reacted with the sulphuric acid in the floc reduction tank. By washing the oil-floc mixture with sulphuric acid, the iron hydroxide floc is dissolved and forms ferrous sulphate. The ferrous sulphate is decanted from the bottom of the vessel for reclamation or neutralization.



FLOC FORMATION AND REGENERATION



stelco

Slide VI

The oily portion is then blended with the oily material from the concentrated oil batching stage for further refining as previously described.

Slide VII. Normally the treatment of oily water generates more iron sulphate solution than is necessary for internal chemical use. The excess iron solution is neutralized with lime. The resultant slurry is filtered and the solids are disposed as landfill. The water is returned to the recovery system for reprocessing. The chemistry can be simply stated as follows:-



Slide VIII



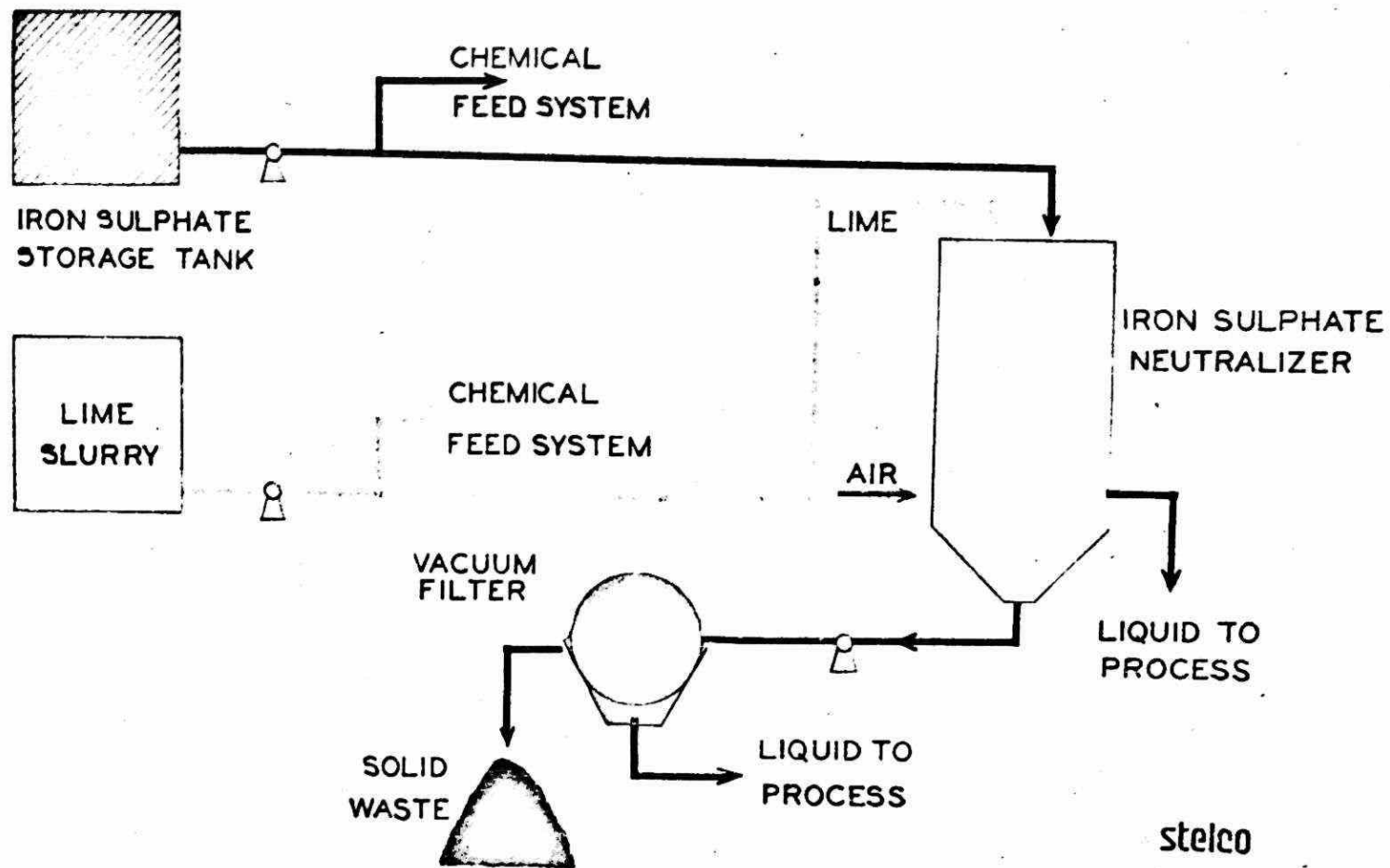
In summary then the process has the basic components to achieve:

- (1) A treated water effluent
- (2) Dry, clean oil for internal utilization.
- (3) Generation of minimal inert grit for disposal.

However, with any new plant some problems will be encountered and this system is no exception.

The concentration of oil in the spent rolling solutions fluctuates. Unfortunately, the chemical dosage demand to effectively treat the waste water requires a prior knowledge of the degree of contamination, yet the technology for continuously measuring accurately oil concentrations are not available. Adjustment to the feed rates must, therefore, be made on the basis of individual laboratory tests. The response to rapid fluctuation in oil concentrations is less than instantaneous. Experienced operators are required and perform a vital function in observing the general performance of the plant and the manner in which the floc forms and floats. In a nut shell, some art is required to operate the plant successfully. Some of these skills are still being learned today. As an important guide for controlling the recovery

NEUTRALIZATION PROCESS



Slide VII

IRON SULPHATE NEUTRALIZATION



stelco

Slide VIII

operation, the Operator must be aware of the status of the rolling solutions which are being used and information such as the age, rate of application and the expected disposal time of spent rolling solutions are of importance. With this prior knowledge, some upsets in the treating system can be avoided. Some specific problems which have been overcome through field experimentation and process design changes may be of interest.

pH Adjustment

Initially, the plant was operated at a recommended pH of seven. Operating in this mode resulted in very high soluble iron in the discharge water. Plant stability could not be maintained and late floc formation occurred. After running the plant within a pH range from 5 to 11 under controlled conditions, the optimum pH was found to be in the range of 8.5 to 10. In this range, much greater stability was achieved.

Chemical Feed System

In operating the water system as described previously in Slide V, the design specifications were not approached consistently. The plant was designed to meet the following standards:--

suspended solids - less than 15 P.P.M.

oils - less than 10 P.P.M.

The typical operating range during a 30 day test period was as follows:- Slide IX

PHASE I - INITIAL START-UP

	Maximum PPM	Minimum PPM	Average PPM
<u>Suspended Solids</u>	307	15	111
<u>Carbon tetrachloride</u> <u>Extractables (oil)</u>	275	8	76

PLANT DESIGNED TO GIVE:—

SUSPENDED SOLIDS — LESS THAN 15 PPM

OILS — LESS THAN 10 PPM

	PHASE 1 INITIAL START-UP			PHASE 2 RELOCATION OF CHEMICAL INJECTION			PHASE 3 POLYELECTROLYTE ADDITIONS		
	MAXIMUM P.P.M	MINIMUM PPM	AVERAGE PPM	MAXIMUM PPM	MINIMUM PPM	AVERAGE PPM	MAXIMUM PPM	MINIMUM PPM	AVERAGE PPM
SUSPENDED SOLIDS —	307	15	111	320	11	80	120	3	39
CARBON TETRACHLORIDE- EXTRACTABLES (OIL)	275	8	76	306	2	50	188	3	20

SLIDE IX

On the basis of these test results, an investigation revealed that:--

- (1) The lime was not fully dispersed in the water which hindered the reaction with the dissolved iron.
- (2) The floc formation was incomplete and on occasion occurred after the air release. The delay resulted in suspended solid carryover.
- (3) The fragile iron hydroxide floc was being sheared by the pump impeller. Slide X

Other injection points were used but found not to be as effective. Subsequently, the chemical injection point for the iron solution was changed to the discharge side of the main water pumps. The change was prompted to overcome inefficiencies in the mixing and to reduce floc degradation.

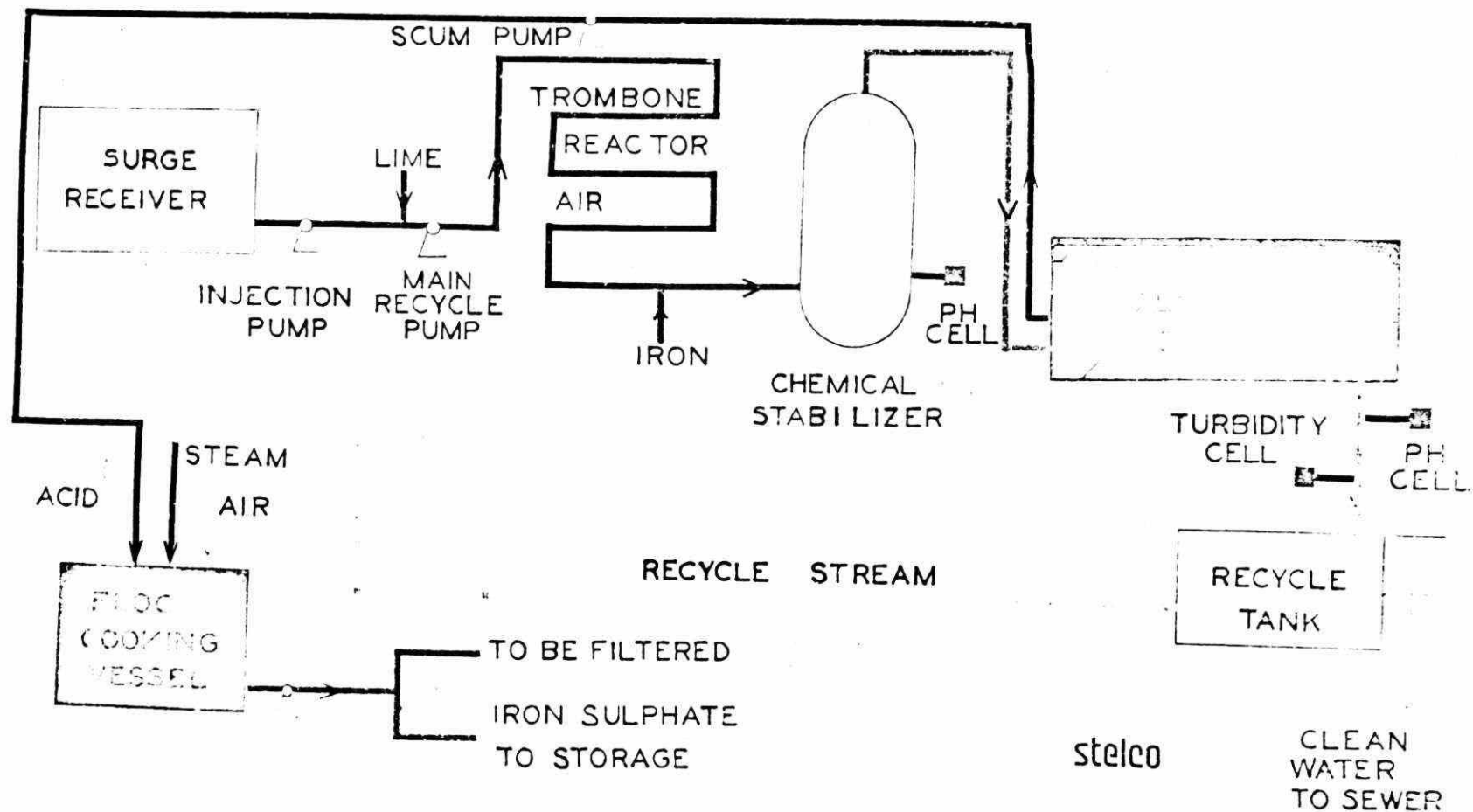
This adjustment solved the problem of mixing the lime, but the suspended solid carry over did not drop significantly. The iron floc still appeared to be shearing and, eventually, the baffles in the pipe reactor were reduced in size. Furthermore, to ensure sufficient time for the floc to form, a chemical stabilizer tank was added. These additional changes provided greater stability and improved the quality of the effluent. The average plant effluent under these conditions for another 30 day test period were: Slide IX

PHASE 2 - RELOCATION OF CHEMICAL INJECTION

	Maximum PPM	Minimum PPM	Average PPM
<u>Suspended Solids</u>	320	11	80
<u>Carbon tetrachloride</u>	306	2	50
<u>Extractables (oil)</u>			

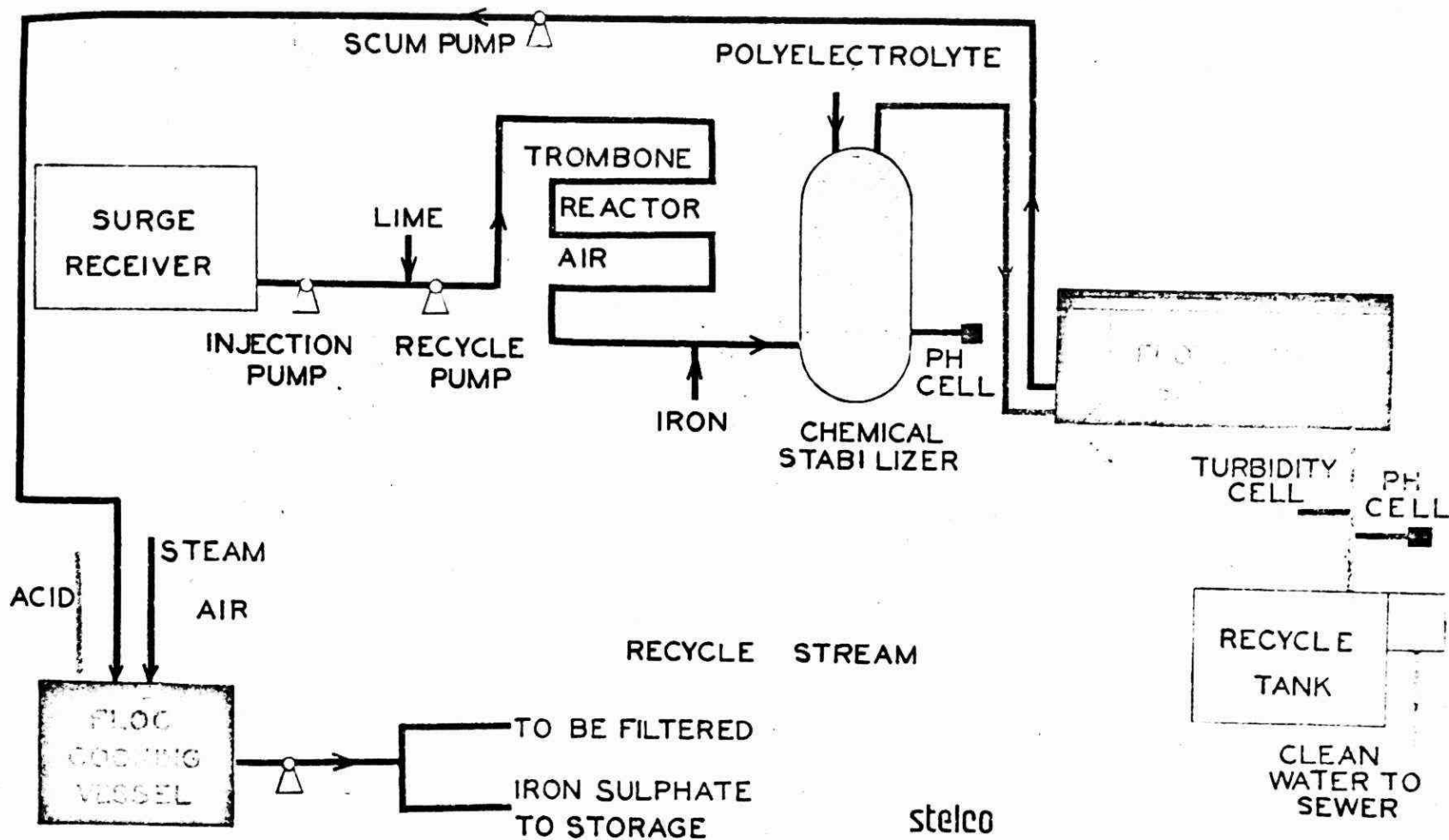
Slide XI Additional investigations revealed that the floc could be compacted and stabilized through the additions of polyelectrolytes. Various types of polyelectrolytes were tested to aid in the agglomeration and cohesiveness of the floc. The

WATER TREATMENT-PHASE II



Slide X

WATER TREATMENT—PHASE III



Slide XI

polymer was ultimately added at the discharge pipe of the chemical stabilizer tank with a dosage of 1 ppm. The effluent was sampled for 28 days. During this period, the plant ran 50% of the time under 15 ppm of suspended solids and 10 ppm of oil. The average for the entire period was 16.6 ppm of suspended solids. The performance on the basis of residual oils was satisfactory.

Internal System Upsets Slide XII

On examining certain regular upsets, it was discovered that they occurred whenever neutralized iron solutions were filtered. The material was being filtered on a belt filter. As the drum rotates and the vacuum is applied, the solid builds up on the filter cloth. The cloth which holds the solids, then moves around a set of deflector rolls, which cause the solids to fall off. Water sprays then wash the cloth. The dirty water was reprocessed by pumping the solution to the surge receivers. The solution consistently had a high suspended solid loading with values as high as 100,000 ppm of suspended solids.

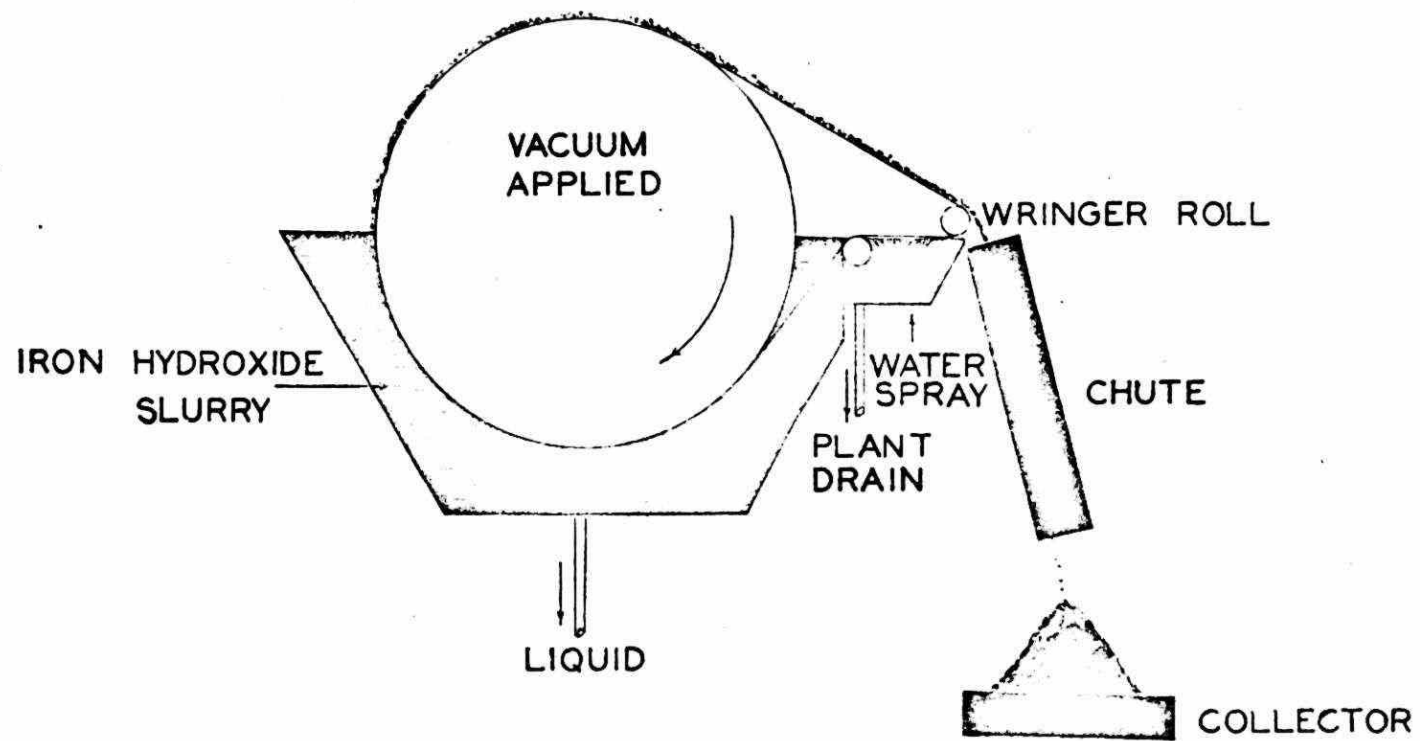
The reintroduction of dirty water with its fluctuating solid level caused chemical imbalances and resulted in uncontrollable plant conditions. The upsets made the plant operation very difficult. Visually, the nature of the floc was changed and it was difficult to remove the fine floc with surface skimmer paddles. The filter has now been changed from a belt filter to a precoat filter. The modification has reduced the uncontrolled recycled load of iron and solids to the system. The consistency and quality of the floc has improved. The solid load returned to the system is in the range of 5 to 60 ppm of suspended solids.

The combination of these modifications have resulted in the following effluent characteristics:--
Slide IX

PHASE 3 - POLYELECTROLYTE ADDITIONS

	Maximum PPM	Minimum PPM	Average PPM
<u>Suspended Solids</u>	120	3	39
<u>Carbon Tetrachloride</u>	188	3	20
<u>Extractables (oil)</u>			

BELT FILTER



steico

Slide XII

- 229A -

The results of this installation can possibly be demonstrated on the basis of the oil recovery efficiency. Under these operating conditions, it has been found that 99% of the emulsified oil and fat contaminants can be removed with the chemical treatment system.

The concept of batch treating concentrated solidified oils and breaking oil-water emulsions with pH control is sound. However, the success of removing oil from the water using an iron floc and air flotation is not entirely predictable. The treatment is further complicated because a number of proprietary stabilizers are used for different rolling oil blends. All these variations, together with fluctuations in flow and oil concentration, influence the floc formation. Once the oil-water emulsion has been separated, the efficiency of the recovery system depends on the skimming operation to remove the floc from the surface of the water. The floc must therefore float and be cohesive. A finely dispersed floc will not be captured by the skimmer and, consequently, will be discharged in the overflow. The main efforts in modifying the system were directed towards improving the floc formation. Some changes have been successful in achieving a greater degree of plant reliability and effluent quality. Because of a host of factors, most of which cannot be controlled or continuously measured, one can expect that the efficiency of treatment will fluctuate.

In our assessment, the total facility, which was constructed at a cost of 2.5 million dollars, represents a suitable installation for the treatment of spent rolling solutions. Whereas collection of oil was practiced in former years, using a 600,000 dollar facility, the degree of treatment was judged inadequate by today's standards and a totally new system was necessary. Although considerable capital was invested, we are continuing to work together with the supplier to improve the consistency of the plant performance. Oil recovery and suspended solid removal methodology for our situation requires both science and art and probably more of the latter. Additional time will be required to tune the operation.



"21 Years - A Look at The Industrial
Waste Conference"

BY

D. S. CAVERLY

Chairman

D. S. CAVERLY

Environmental Hearing Board

Mr. Chairman, Head Table Guests, Ladies and Gentlemen:

It is a pleasure to be here tonight and I am flattered that you have asked me to be your Banquet Speaker. Rather than spending the next half hour in lighthearted humour, I would like to reminisce a bit on the Industrial Waste Conferences of the past, those who first conceived them, how they progressed over the years and those who made valuable contributions to them. I would also like to review the Industrial Waste picture in Ontario, the changes in concept and approach that have developed over the years and, if time permits, I shall attempt to take a look into the future.

The first Industrial Waste Conference was held in 1954, - 20 years ago. It took place at the Ontario Agricultural College in Guelph and was sponsored by the Pollution Control Board of Ontario. This was a body of senior civil servants appointed by the then Premier, Leslie Frost, and whose duty was to review the water pollution picture in Ontario and advise the Government on the course of action necessary to solve the problems. Its members were:

Department of Health

Dr. A.E. Berry

Chairman, Pollution Control
Board Director, Sanitary
Engineering Division.

A.V. Delaporte

Chemical Engineer, Officer-in-
Charge of Experimental Station

Department of Lands and Forests

F.W. Beatty	Sureyor General
W.J.K. Harkness	Chief, Division of Fish and Wildlife

Department of Agriculture

G.H. Ruhnke	Director of Research
-------------	----------------------

Department of Planning and Development

A.H. Richardson	Conservation Engineer Conservation Branch
-----------------	--

Ontario Research Council

W.J. Mackey	Secretary, Research Council
-------------	-----------------------------

Department of Mines

D. Douglas	Executive Officer
------------	-------------------

Department of Municipal Affairs

A.T. Butler	Supervisor
-------------	------------

I had the dubious honour of being the Board's secretary. I might say that this Board took its responsibilities seriously; it studied the pollution picture in Ontario in detail, it held hearings throughout the Province and conceived the Industrial Waste Conference.

Above all else, it recognized that industrial waste was an emerging problem in the water pollution field. I would like to quote from the preface of the printed Proceedings from that first conference:

"Industrial wastes are one part of the pollution problem which faces all countries today. Municipal sewage is the other. Ontario is growing industrially at a fast pace. The problems involved in waste disposal are many and complex. They change rapidly with the development of new processes and new products. This first conference dealt with some of the many industrial wastes. Publication of the papers in this brochure is done with the objective of making this information available to a large number of persons and in that way to aid in the program of pollution abatement and control. The Pollution Control Board is concerned with the effects from all kinds of pollution.

The Board members come from those departments of Government interested in or having obligations in respect to pollution control. By acting jointly as a Board there can be co-ordination of efforts irrespective of the effect pollution may have on the many uses which are made of water and air in this Province."

The driving force behind the Conference, in those days, was "Cap" A.V. Delaporte and, of course, "Doc" A.E. Berry. Two conferences were held in Guelph and then it was time to move because of the increased use of the Ontario Agriculture College facilities for more agriculturally-oriented conferences. Cap Delaporte had the theory that if you could attract "top management" to the Conference and expose them to the industrial waste problem, management decisions to undertake the correction of industrial waste problems would more likely be made. When we left Guelph, we picked a location which would be attractive to senior management by moving the Conference to Delawana Inn at Honey Harbour. Cap's theory, however, did not work out too well. For a couple of years, we did have some senior people in attendance but it became apparent that the Conference was becoming oriented to technical considerations and we decided, therefore, to make it the best technical conference of its kind in Canada. To achieve this, we resolved to bring in outside speakers whom Ontario delegates to the Conference would not normally have an opportunity to hear. We stayed at Delawana Inn for eight years (1956-63), by which time we had out-grown the accommodation at the hotel. In fact, the Conference had taken on the unofficial name of the "Honey Harbour Conference." When looking around for another location, we recognized the value of a semi-isolated location at which to hold the Conference, so that we might have a more or less "captive" audience. It had also come to be realized that the "after hours" discussions which took place in the lobby of the hotel, or in the rooms, was an important feature of the Conference. With this in mind, we moved to Bigwin Inn in the Muskokas but, being on an island, it turned out to be a little too isolated and hard to reach. Furthermore, at that particular time, the hotel was somewhat run down. Consequently, we only stayed at Bigwin for two years and then moved on to Niagara Falls and the Park Motor Hotel.

At this time, the Pollution Control Board of Ontario had long since disappeared. The OWRC had been formed and for a couple of years, the Conference was sponsored by what was referred to as the "Water and Pollution Advisory Committee of the OWRC." Then the OWRC took over the sponsorship of the Conference and set up a small conference committee to run it. This Committee was composed of Dennis Caplice, Fred Voegelé, Len Tobias and myself and this Committee ran the Conference until last year. Fred Voegelé and I are now with the Environmental Hearing

Board; Len Tobias is with the Ministry of Government Services and only Dennis Caplice remains of the old committee.

Time does not permit me to mention all of the early supporters and contributors to the early Conferences, but in addition to Cap Delaporte and Doc Berry, I would like to mention the following:

- Alex McRae and Dr. Stratford of Imperial Oil
- Hayse Black of the U.S. Public Health Service
- Gordon Henderson of Sun Oil
- Wes Eckenfelder of Manhattan College
- Rupert Kountz of Penn State University
- Dr. Boruff of Hiram Walkers
- B.C. Newbury and Lorne Campbell of the Ontario Research Foundation
- Fred Gurnham of Michigan State University
- Dr. Clarence Tarzwell of U.S. Public Health Service
- Robert Mills of Naugatuk Chemicals
- Ken Mayall of Dept. of Energy and Resources
- Jim Kinney of James F. MacLaren
- Hugo Holland of Imperial Oil Enterprises
- Jim Duncan of OWRC
- Doug Jones of the Canadian Pulp & Paper Association
- Min Yatabe of Gore and Storrie Ltd.
- Murray Sobolov of Hiram Walkers
- Jack Norman and Keith Murphy of McMaster University
- Lorne Van Luven of Montreal
- Tom Beak of Kingston
- Dr. Ross McKinney of M.I.T.
- Dick Millest - then Director of Industrial Waste, OWRC
- Mae Grove, Assistant for a number of years to Doc Berry

Our stay at the Park Motor Hotel was for only two years (1966 and 1967) and then we moved down the street to the Sheraton Brock Hotel. By this time, the social side of the Conference had developed substantially. While maintaining the high calibre of the technical papers, we encouraged the attendance of the ladies and they had their own social programs. We had dances and "happy hours" after 5 and outside banquet speakers for a change of pace. You will remember the Rev. Harry S. Rodney from St. Thomas and the humour which he interjected into the Conference. Remember the famous "food poisoning" after one of our annual banquets when, the next morning, everybody had the "Sheraton Two-Step" and we were afraid to get in a car for even an hour-drive home.

By 1972, everybody was tired of Niagara Falls. We had been there for five years and the girls had seen all the sights that there were to see, so in 1972 we moved to Toronto and to the Skyline Hotel, where we have been for the last three years.

Before I conclude my reminiscing, I must pay tribute to the Ministers and Chairmen of the OWRC without whose support these Conferences would not have been possible. I would particularly like to mention:

- Dr. MacKinnon Phillips - Minister of Health, 1954
- OWRC Chairmen: Mel Snider
Jim Vance
Don Collins
Bob Johnston
John Root
- The recent Minister of the Environment, Jim Auld and the present Minister of the Environment, Bill Newman.

Let me turn now to a summary of what I think we have accomplished in these 21 conferences (over and above the 21 receptions and 21 annual banquets). I believe the conferences, among other things, have made two important contributions to this Province. They have focussed attention on the importance of industrial waste treatment in the pollution control field and they have been responsible for the production of top notch papers on the latest technology of industrial waste treatment.

These are changing times, however, and industrial waste can no longer be considered in isolation from other environmental concerns. It is but part of the total environmental management picture and, of course, industry is not concerned with water pollution alone. It must be concerned with air pollution as well as solid waste management.

In looking over the years, I believe Ontario has made considerable progress in the industrial waste treatment field. Admitted, there is still industrial pollution around and there always will be a certain amount, but Ontario does not take a back seat today to any other jurisdiction in the area of waste treatment. These are becoming complicated times for industry. An industrialist must not only satisfy the demands of the regulatory bodies, but also those of the environmentalists and the general public as well. There is a growing resentment today to the establishment of industry in any place, other than in well recognized industrial areas. In this connection, environmental impact assessment will soon apply to all industrial establishments, following the passing of the proposed legislation which is presently being prepared by the Ministry of the Environment.

But what about the more distant future? Where will we be by the year 2000 AD and beyond? Certainly there will be more population pressures. There are gloomy predictions that over the next century, population growth, if not stopped, will sweep humanity into a state of disaster. I optimistically would argue that man's ingenuity will continue to solve human problems, even those major ones which world population growth presents. Already we are noting, in this country for example, that the decay of cities, which noticeably accelerated after World War II, is now being significantly slowed down. Regional approaches in the future to problems related to transportation, sewage treatment, water supply, etc., will evolve because they will be less expensive than today's fragmented approach to these problems. Private land will become more public and national and provincial land use laws will control development, with a view to achieving broader benefits.

The relentless increase in population around the world will undoubtedly raise the price of everything, including one thing which the world very much takes for granted ... water. Even now, most of the easy sources of water have been exploited. The water which remains will become more expensive each year to obtain, treat and deliver. By the year 2000 AD, water will no longer be subsidized as it often is now. Water will be paid for at its market value, like food, shelter and energy. The result will be more efficient use of water, with cleaner streams and new imaginative schemes of obtaining new sources. Many communities will build advanced waste water treatment facilities, which will produce a sewage effluent of drinking water quality. Certainly, when waste water is made good enough to drink, it becomes too good to throw away. I predict that many communities in the future will recycle their waste water for municipal use.

One of the most demanding problems of the future will be the disposal of solid wastes. The high cost of

waste disposal, the concern for the environment and the rising cost of raw materials, will ultimately lead us to recover our refuse - to recycle the metals, glass and fibres and to use the heat from the incineration of the remainder to produce steam or electricity. The four "design" professions - architecture, engineering, planning and landscape architecture - will work as a team, with the aid of behavioural scientists, to produce man-made environments, which are conducive to better living, to stable neighbourhoods and the establishment of attractive city centres.

I could go on tonight to discuss tomorrow's housing problems, our expanding energy requirements and, indeed, more could be said as well about problems related to the environment, but I have spoken long enough. It has been, indeed, a pleasure to attend this Banquet and contribute, I hope, in some small way, to the obvious success of this 21st Conference. Thank you for inviting me. I wish you well in the days ahead.

A P P E N D I X

LIST OF DELEGATES WHO ATTENDED THE 21ST ONTARIO INDUSTRIAL WASTE CONFERENCE

Ed Adair
Deputy Reeve
Town of Blenheim
Ontario

J. Adamski
Scientist
Laboratory Services Branch
Resources Road
Box 213
Rexdale,
Ontario

John E. Allen
Eng. Technologist
EPS Ontario Region
135 St. Clair Avenue W
Toronto, Ont.

John T. Allin
Water Quality Biologist
Sports Fisheries Branch
Ministry of Natural Resources
Room 4622
Whitney Block
Queen's Park
Toronto, Ont.

Tom Armstrong
Assistant Director
Northeastern Region
Ministry of the Environment
469 Bouchard Street
Regency Mall
Sudbury, Ont.

R. S. Aston
Pollution Control Director
Courtaulds (Canada) Limited
Montreal Road
Cornwall,
Ontario

C. H. Atkinson
Executive Engineer
Acres Consulting Services Limited
5259 Dorchester Road, North
Niagara Falls L2E 6N8
Ontario

Arthur Bannon
Supervisor - Services
Union Carbide Canada Limited
Box 5400
Belleville, Ont.

Harry Barker
Sales Engineer
Neptune Meters Limited
3526 Lakeshore Boulevard W
Toronto M8W 1N7
Ontario

Thomas J. Barry
Staff Engineer
Shell Canada Limited
Sarnia Refinery
Corunna, Ont.

John Barnwell
Senior Chemist
Reg. Municipality Ottawa-Carleton
Works Department
222 Queen Street
Ottawa, Ont.

E. T. Barrow
Head - New Technology
Air Resources Branch
880 Bay Street
Toronto, Ont.

William Bates
Interflow Systems Limited
Box 3004
Station 'C'
Hamilton, Ont.

Dr. R. Batstone
Industrial Chemist/Consultant
Tara Mines Limited
Kells Road
Navan, Co. Meath
Ireland

J. Baxter
Sweco Canada Limited
22 Jutland Road
Toronto M8Z 2G9
Ontario

Brian Beatty
Hydrogeologist
Hydrology Consultants Ltd.,
Mississauga
Ontario

Leo Behie
Research Engineer
Domtar Research
Senneville H9X 3L7
Quebec

Lawson Bell
Field Representative
Calgon Canada
27 Finley Road
Bramalea, Ont.

A. V. Berdusco
General Manager-Raw Materials
Algoma Steel Corporation
Sault Ste. Marie
Ontario

D.H. Beswick
Chief Stationary Eng. & Pollution Control
Douglas Aircraft
Malton, Ont.

Ken Bethune
Director, Resource Recovery
American Can of Canada
1 International Boulevard
Rexdale, Ont.

Dr. J. K. Bewtra
Professor of Civil Engineering
University of Windsor
Windsor N9B 3P4
Ontario

S. Bhella
Stone & Webster Canada Limited
60 Adelaide Street E
Toronto, Ont.

R. C. Reid-Bickwell, P.Eng.,
Dowlesland Engineering Limited
23 Westmore Drive
Toronto, Ont.

Fred Biesenthal
Jr. Engineer
FENCO
1 Yonge Street
Toronto, Ont.

J. E. Bindon
Sales Engineer
EIMCO
165 Cartwright Avenue
Toronto, Ont.

S. C. Blodgett
Process Chemist
Cyanamid of Canada Limited
Box 240
Niagara Falls, Ont.

Bob Bourice
Jr. Engineer
Tottem Sims Hubicki
1500 Hopkins Street
Whitby, Ont.

Ken Bradley
Senior Chemist - Pollution Control
Uniroyal Chemical
Elmira, Ont.

Mr. C. R. Browne
Senior Project Officer
Ontario Research Foundation
Sheridan Park, Ont.

Stan Bobrow
Engineer
SNC Inc.
1550 De Maisonneuve W
Montreal, Quebec

Luc Bois
Associate Professor
Ecole Polytechnique
Case Postale 6079
Succ. A.
Montreal H3C 3A7
Quebec

James M. Brooker
Sales Engineer
Dorr-Oliver-Long
174 West Street S
Orillia, Ont.

C. R. Brown
Chief Chemist
Redpath Sugars
95 Queens Quay E
Toronto, Ont.

Claude E. Buck
Chief Stationary Engineer
RCA Midland Limited
Wye Valley Road
Midland, Ont.

John Budz
Process Engineer
Crane Canada Limited
Cochrane Division
1355 Martin Grove Road
Rexdale, Ont.

Dino A. Buratto
LaFontaine Cowie Buratto & Assoc. Ltd.,
3260 Devon Drive
Windsor N8X 4L4
Ontario

A. Joseph Burnham
Spec. Project Engineer
Ministry of the Environment
Solid Waste Unit
135 St. Clair Avenue W, 7th Floor,
Toronto M4V 1P5
Ontario

W. R. Cale
Manager - Patents & Information
Erco Industries Limited
2 Gibbs Road
Islington M9B 1R1
Ontario

Hugh Calvert
Eng. Technologist
Alcan Canada Products
P.O. Box 2000
Kingston, Ont.

Hugh Carter
Manager
Ecodyne Limited
2201 Speers Road
Oakville, Ont.

C. William Case
Todgham & Case Limited
P. O. Box 386
Chatham N7M 5K5
Ontario

C. B. Caswell
Supervisor - Environmental Control
Allied Chemical Canada Limited
P.O. Box 2000
Amherstburg N9V 2Z6
Ontario

Chong Chai
Process Engineering Supervisor
Eddy Forest Product Limited
Espanola,
Ontario

R. Chii
Stone & Webster Canada Limited
60 Adelaide Street E
Toronto, Ont.

G. C. Chisamore
District Officer, Mun. & Private
Central Region
Ministry of the Environment
4375 Chesswood Drive
Downsview, Ont.

Jim Chisholm
District Enforcement Officer
Metro Toronto Works Department
11th Floor E Tower
City Hall
Toronto, Ont.

M. A. Chomyn
Sales Engineer
Envirotech Limited
165 Cartwright Avenue
Toronto, Ont.

Jean Choquet
Co-ordinator - Environmental Affairs
Gulf Oil Canada Limited
Montreal Refinery
3501 Broadway Mtl-East
Montreal H1B 5K1
Quebec

J. H. Christiansen
Industrial Wastes Engineer
Falconbridge Nickel Mines Limited
Falconbridge, Ont.

Adam Ciulini
Project Engineer
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

F. G. Claggett
Technical Advisor
Environmental Protection Service
3rd Floor - 1090 W. Pender Street
Vancouver, B.C.

Harvey H. Clare
Environmental Co-ordinator
Imperial Oil Limited
111 St. Clair Avenue W
Toronto, Ont.

R. R. Clarkson
Tricil Waste Management Limited
701 Evans Avenue, Suite 410
Etobicoke, Ont.

W. K. Clawson
President
M. M. Dillon Limited
P.O. Box 219
Station 'K'
Toronto M4P 2G5
Ontario

John Coates
Senior Planner
Hamilton Region Conservation Authority
838 Mineral Springs Road
Ancaster, Ont.

Arieh Cohen
Approvals Engineer
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

Tom Cole
Environmental Liaison Engineer
Stelco
100 King Street
Hamilton, Ont.

Nels Conroy
Chief - Water Resources
Ministry of the Environment
469 Bouchard Street
Sudbury
Ontario

K. Courillon
Acting Liaison Officer
IMC (Canada) Limited
P.O. Box 70
Dunnville, N1A 2Y6
Ontario

C. W. Crosgrey
Manufacturing Director
Lever Detergents Limited
1 Sunlight Park Road
Toronto M4M 1B6
Ontario

William J. Gosgrove
Plant Superintendent
Sobin Chemicals (Canada) Limited
P.O. Box 280
Havelock, K0L 1Z0
Ontario

Robert E. E. Costello
Senior Vice-President
Corporate Services
Abitibi Paper Company Limited
Toronto Dominion Centre
Toronto, Ont.

W. S. Cotton
Principal Chemical Engineer
Du Pont of Canada
P.O. Box 2100
Kingston K7L 4Z6
Ontario

E. H. Coulter
Research Metallurgist
Falconbridge Nickel Mines
8810 Yonge Street
Box 900
Thornhill, Ont.

H. Cox
Manager - Plant Engineering
RCA Limited
Wye Valley Road
Midland, Ont.

G. R. Craig
Ministry of the Environment
Water Resources Branch
P.O. Box 213
Rexdale M9W 5L1
Ontario

G. B. Crawford
Vice-President
Gore & Storrie Limited
1670 Bayview Avenue
Toronto M4G 3C2
Ontario

W. A. Creighton
Chief, Water Resources Assessment
Ministry of the Environment
1111 Victoria Avenue
Thunder Bay, Ont.

A. J. Crouse
Director
Nova Scotia Department of the Environment
P.O. Box 2107
Halifax, N. S.

Nestor J. Czornyj
Laboratory & Environmental Superintendent
Sun Oil Company Limited
P.O. Box 307
Sarnia N7T 7J3
Ontario

William G. Dallas
Conservation Manager
Tara Mines Limited
Kells Road
Navan, Co. Meath
Ireland

Frank Darcel
Scientist
Ministry of the Environment
Resources Road
Rexdale, Ont.

C. B. Davis, P. Eng.,
Vice-President
Giffels, Davis & Jorgensen Limited
30 International Boulevard
Rexdale M9W 5P3
Ontario

John Day
Staff Engineer - Environment
Abitibi Paper Company Limited
Sheridan Park
Ontario

Keith Dermott
Councillor
Township of Tecumseth
R. R. # 5
Cookstown, Ont.

D. T. Dickson
Senior Design Engineer
Environmental Control
Du Pont of Canada Limited
P.O. Box 2100
Kingston, Ont.

P. M. Dixon
Environmental Sales
Dorr Oliver Long
174 West Street S
Orillia, Ont.

Alec Dobson
Municipality of Metropolitan Toronto
Main Treatment Plant
1091 Eastern Avenue
Toronto, Ont.

John H. Dowler
Process Design Engineer
Tricil Waste Management Limited
701 Evans Avenue, Suite 410
Etobicoke M9C 1A3
Ontario

Bruce R. Dreisinger
Environmental Effects Specialist
International Nickel Co. of Canada
Copper Cliff, Ont.

Thomas W. Drew
President
D & D Disposal Services Limited
P.O. Box 402
Beamsville, Ont.

Robert J. Dubeau
Project Manager
W. J. Cosgrove & Assoc.
2600 Ontario, East. Suite 220
Montreal, Quebec

Robert J. Duchominsky
Industrial Waste Supervisor
City of Winnipeg
455 Ellice Avenue
Winnipeg, Man.

Dave Durant
Ont. Sales Manager
Wallace & Tiernan
925 Warden Avenue
Scarborough, Ont.

P. C. Eberlee
Director
Totten Sims Hubicki Limited
1500 Hopkins Street
Whitby, Ont.

Kamal Elguindi
Approvals Engineer
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

A. C. Elliott
793 Forest Glen Avenue
Burlington, Ont.

Maurice O. Gagnon
Environmental Officer
Ministry of the Environment
765 Barrydowne Road
Sudbury, Ont.

John Faust
Chemist, Pollution Control Officer
Corporation City of Windsor
4155 Ojibway Parkway
Windsor, Ont.

Dr. J. Ganczarczyk
Associate Professor
University of Toronto
Department of Civil Engineering
Toronto, Ont.

W. F. Fell
Director, Environmental Control
The Ontario Paper Co., Ltd.,
Thorold, Ont.

Dr. H. R. Eisenhauer
Chief, Water Quality Research Division
Water Quality Branch
Environment Canada
Place Vincent Massey
Ottawa K1A 0E7
Ontario

W. C. Ferguson
Supt. of Environmental Control
Inco
Copper Cliff, Ont.

Hugh Fielding
Hugh Fielding Limited
55 Glen Cameron Road
Thornhill, Ont.

H. W. Embleton
Process Engineer
Shell Canada Limited
505 University Avenue
Toronto M5G 1X4
Ontario

Gerald Fisher
Corporation Town of Goderich
Goderich, Ont.

M. Carol Emond
Engineer
Quebec Government - Environment
Edifice "D"
Quebec City
Quebec

Leslie Fitz
District Officer
Ministry of the Environment
765 Barrydowne Road
Sudbury, Ont.

Thomas E. Eyre
Project Engineer - Pollution Abatement
Lee Engineering Limited
P.O. Box 876
361 Elgin Street
Brantford, Ont.

A. D. Fitzgerald
Director - Process Design
Montreal Division
Beak Consultants Limited
540-4999 St. Catharines Street W
Montreal, Quebec

Grahame J. Farquhar
Professor
University of Waterloo
Waterloo, Ont.

D. W. Flood
Engineer
Maple Leaf Mills Limited
417 Queen's Quay W
Toronto, Ont.

R. L. Ford
Sales Manager
The Goodfellow Group
Division of Tricil Waste Management
551 Avonhead Road
Mississauga, Ont.

Talis Forstmanis
Chemical Analyst
Goodfellow Enterprises (Sarnia) Ltd.,
Box 786
Corunna, Ont.

C. S. Fox-Revelt
Vice-President
Security Recycling Limited
230 Creditstone Road
Maple, Ont.

F. Frantisak
Supervisor
Ministry of the Environment
880 Bay Street
Toronto, Ont.

Gordon Fraser
Superintendent, Site Services
Alcan Canada Products
P.O. Box 2000
Kingston, Ont.

J. G. Fry
District Officer
Ministry of the Environment
1083 Barton Street E
Hamilton, Ont.

Herb Freedman
Manager
Enviroclean Limited
435 McNicoll Avenue
Willowdale, Ont.

Gunther Funk
Geologist
Ministry of the Environment
40 St. Clair Avenue W
Toronto, Ont.

Richard F. Gabbey, P. Eng.,
Chief Environmental Engineer
W. H. Crandall & Assoc. (Mgt.) Ltd.,
P.O. Box 36
Moncton, E1C 8R9
N. B.

Alex Garklavs
Project Engineer
Arthur G. McKee
207 Queen's Quay West
Toronto M5J 1A7
Ontario

P. Gangopadhyay, P. Eng.,
Canplan Consultants Limited
P.O. Box 2315
6074 Lady Hammond Road
Halifax, Nova Scotia

M. German
Biologist, Technical Support Section
Regional Operations Division
Ministry of the Environment
Southeastern Region
1055 Princess Street
Kingston, Ont.

J.P. Gifford, P. Eng.,
Technical Services Engineer
Canadian Industries Limited
P.O. Box 1299
Cornwall, K6H 5V4
Ontario

Bob Gillespie
Chemical Engineer
Dames & Moore
Consultants in Environmental Sciences
40 University Avenue, Suite 232
Toronto, Ont.

Harold Graham
President
Quinte Sanitation Services Ltd.,
Box 462
Belleville, Ont.

Peter Grant
Water Quality Control Engineer
Alberta Environment
10040 - 104 Street
Edmonton, Alberta

M. S. Greenfield
Air & Water Quality Engineer
Dominion Foundries & Steel Ltd.,
Box 460
Hamilton, Ont.

J. L. Greer, P.Eng.,
Vice-President
W. L. Wardrop & Associates Ltd.,
300 - 77 Main Street
Winnipeg, R3C 3H1
Manitoba

Milt Greer
Mayor
Town of Blenheim
Ontario

Charles R. Griffiths
Plant Engineer
Rockwell International of Canada Ltd.,
R. R. # 2
Parry Sound, P2A 2W8
Ontario

Fred Groch
Environmental Engineer
Nisbett Letham Limited
206 Water Street
Sarnia, Ont.

Gregory J. Grondin
Technologist - Chemistry
Canadian Cannery Limited
Research Centre
1101 Walkers Line
Burlington, L7N 2G4
Ontario

William E. Grove
General Superintendent - Services
L.O.F. Glass of Canada Limited
Collingwood, Ont.

Frank Guillaume
Manager
L. S. Love & Assoc. Ltd.,
158 Kennedy Road S
Brampton, Ont.

H. O. Haatainen
Industrial Sales Representative
Allied Chemical Canada Ltd.,
100 N. Queen Street
Toronto, Ont.

T. M. Hamilton
Manager - Materials Engineering
Chrysler Canada Limited
Chrysler Centre
Windsor, Ont.

Walter Harley
Plant Engineering Manager
Formosa Spring Brewery
P.O. Box 159
Barrie, Ont.

D. Harrison
Managing Engineer
Pollution Abatement Programs
Ontario Hydro
Toronto, Ont.

Victor Havelock
Head, Metallurgical Industries Section
Air Pollution Control Directorate
Environmental Protection Service/Canada
Ottawa K1A 0H3
Ontario

Frank A. Havlik
Sales Manager
Infilco Div. Westinghouse
705 Progress Avenue
Suite B
Scarborough, Ont.

R. S. Hayter
Executive Director
Plastics Industry Council
1262 Don Mills Road
Suite 61
Don Mills, Ont.

F. A. Heilingbrunner, P. Eng.,
Associate Master
Sir Sandford Fleming College
Brealey Drive
Peterborough, K9J 7B1
Ontario

J. G. Henry
J. G. Henry Associates Limited
7 Lichen Place
Don Mills M3A 1X3
Ontario

J. C. Henshaw
Manager Business Development
Cambrian Processes Limited
Mississauga, Ont.

Paul Hicks
Chemical & Environmental Supt.
Ontario Hydro
Lambton C.S.
Box # 2100
Courtright, Ont.

K. B. Hill
Senior Approvals Engineer
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

W. J. Hogg
Head, Mining & Met. Unit
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

David Holden
Public Relations Consultant
Tara Mines Ltd.,
Kells Road
Navan,
Co. Meath
Ireland

W. Holowacz
Area Superintendent
Regional Niagara
Box # 202
Welland, Ont.

Art Hudson
Process Engineer
Crane Canada Limited
Cochrane Division
1355 Martingrove Road
Rexdale, Ont.

J. R. Inch
W. N. Horner & Assoc. Ltd.,
89 Queen Street
Truro, N.S.

B. B. Hillary
Manager, Corporate Services
Dow Chemical of Canada Limited
P.O. Box 1012
Sarnia, Ont.

R. Hussain
Senior Environment Officer
Ministry of the Environment
985 Adelaide Street S
London, Ont.

Paul S. Isles
Senior Environment Officer
Ministry of the Environment
4375 Chesswood Drive
Rexdale, Ont.

Murdoch Jefferson
Senior Municipal Engineer
De Leuw Cather Canada Limited
133 Wynford Drive
Toronto M3C 1K1
Ontario

J. C. Jemison
Water Quality Inspector
Scarborough Works Department
Scarborough New Civic Centre
150 Borough Drive
Scarborough, Ont.

K. K. Kandil
Senior Materials & Process Engineer
Douglas Aircraft of Canada
Malton L5P 1B7
Ontario

James G. Keith
Allied Chemical
100 North Queen Street
Toronto, Ont.

Ashley D. Kemila
Production Manager
Brockville Chemical Industries Ltd.,
Maitland, Ont.

G. Kenny
Industrial Sales Representative
Allied Chemical Canada Limited
100 N. Queen Street
Toronto, Ont.

Colin Keith Kent
Senior Sanitary Engineer
Ainley & Associates Ltd.,
Consulting Engineers
105 Hurontario Street
Collingwood, Ont.

R. R. Kleiber
Engineered Products
Pumps & Softeners Ltd.,
680 Waterloo Street
London, Ont.

Ian D. King
Technical Sales Representative
Goodfellow Enterprises
551 Avonhead Road,
Mississauga, Ont.

P. Knettig
Imperial Oil Enterprises Ltd.,
Engineering Division
P.O. Box 3015
Sarnia N7T 7N1
Ontario

C. H. Knight
Senior Vice-President
Envirotech Canada Limited
165 Cartwright Avenue
Toronto, Ont.

P. D. Knox
Sweco Canada Limited
22 Jutland Road
Toronto M8Z 2G9
Ontario

W. A. Kowalewski
Plant Manager
Ciba-Geigy Canada Limited
1200 Franklin Boulevard
P.O. Box 937
Galt-Cambridge N1R 5X9
Ontario

Ole E. Kristiansen
Co-ordinator of Waste Control
Domtar Fine Papers Limited
800 - 2nd Street W
Cornwall K6H 5S3
Ontario

G. J. LaHaye
District Officer
Ministry of the Environment
445 Albert Street E
Sault Ste. Marie, Ont.

Donald Cameron Lamond
Manager, Chemical Division
Brockville Chemical Industries Ltd.,
Maitland, Ont.

E. A. Lancaster
Manager, Flocor Products
Canadian Industries Limited
130 Bloor Street W
Toronto M5S 1P4
Ontario

Robert C. Landine
ADI Limited
P.O. Box # 44
Fredericton, Ont.

Mr. Earl LaRocque
Plant Metallurgist
Denison Mines Limited
Box # B.2600
Elliot Lake, Ont.

W. G. Lobban
Supervising Project Engineer
Ontario Hydro
620 University Avenue,
Toronto, Ont.

Peter Laughton
Associate
R. V. Anderson Assoc. Ltd.,
194 Wilson Avenue
Toronto, Ont.

Syd Love
President
L. S. Love & Assoc. Ltd.,
158 Kennedy Road S.
Brampton, Ont.

Brian Leahy
Process Investigator
Pfizer Co., Ltd.,
P.O. Box 7
Wallrich Avenue
Cornwall, Ont.

Richard Luscombe
Project Co-ordinator
L. S. Love & Associates
158 Kennedy Road
Brampton, Ont.

Sergio Legati
Vice-President Manufacturing
Tonolli Co. of Canada
2414 Dixie Road
Mississauga, Ont.

Terence B. Lynch
Technical Superintendent
Canadian Industries Limited
P.O. Box # 1900
Courtright, Ont.

W. J. Leisten
Superintendent, Pollution Control
BASF-WYANDOTTE Corporation
1609 Biddle Avenue
Wyandotte 48192
Michigan, U.S.A.

J. F. MacDonald
Environmental Control Supervisor
International Nickel Co. of Canada Ltd.,
Davis Street
Port Colborne, Ont.

Victor W. Lesnicki
Regional Inspector Water Pollution
Regional Municipality of Halton
Halton, Ont.

W. Blair MacDonald
Utility Works Supervisor
Prince Edward Is. Environmental Control
Commission
P.O. Box 2000
Charlottetown, P.E.I.

Charles Leung
Chemical Engineer
Union Carbide Canada Limited
150 Colborne Street E
Lindsay, Ont.

Robert MacDonald
Field Services Technologist
Regional Municipality of Waterloo
8 Bridge Street E
Kitchener, Ont.

G. A. MacDonald
Manager, Facilities
IBM Canada Limited
Department 515
844 Don Mills Road
Don Mills, Ont.

L. MacDonald
Chief Chemist
St. Lawrence Cement Company
2391 Lakeshore Road W
Mississauga L5J 1K1
Ontario

B. J. MacDougall
Manager - Engineering Services
Consumer Glass Co., Ltd.,
777 Kipling Avenue
Toronto M8Z 5G6
Ontario

L. Maki
Biologist
Water Resources - Northeastern Region
Ministry of the Environment
469 Bouchard Street
Regency Mall
Sudbury, Ont.

H. Leslie MacMillan
Solid Waste Supervising Engineer
Regional Municipality of Peel
150 Central Park Drive
Bramalea, Ont.

Richard P. Mair
Manager, Environmental Control
Dow Chemical of Canada Limited
Box 3030
Sarnia N7T 7M1
Ontario

T. A. Mair
Superintendent Utilities
Steel Company of Canada
Wilcox Street
Hamilton, Ont.

Henry Makuch
Fuel, Chemical & Environmental Supt.,
Ontario Hydro
440 Unwin Avenue
Toronto, Ont.

Steve Mandryk
Chemical Process Control Supervisor
Fiberglas Canada Limited
No. 40 Highway
Sarnia, Ont.

J. T. Manuel
District Officer
Ministry of the Environment
985 Adelaide Street S
London, Ont.

Orlando Martini
Project Engineer
James F. McLaren Limited
435 McNicoll Avenue
Willowdale, M2H 2R8
Ontario

R. A. McCaig
President
Sanitary Collection
R. R. # 5
St. Thomas, Ont.

Dr. J. A. McCoubrey
Manager
Lambton Industrial Society
Suite 201N
242A Indian Road S
Sarnia, Ont.

Ian McKerracher
Director
Refuse Disposal Division
Municipality of Metropolitan Toronto
Toronto, Ont.

Richard E. Matsugu
Rexnord (Canada) Limited
1181 Sheppard Avenue E
Willowdale, Ont.

R. W. Meecham
Sales Manager
Belgium Standard Waste Management
110 Maplecrete Road
Concord, Ont.

H. W. Meyfarth
Editor, Engineering Digest
46 St. Clair Avenue East
Toronto M4T 1N2
Ontario

Mark Morrison
Design Engineer
International Nickel Co.,
General Engineering Department
Copper Cliff, Ont.

T. H. McMullan
Project Engineer
Canadian Industries Ltd.,
630 Dorchester Boulevard West
Montreal, P.Q.

M. Mukerjee
Plant Group Manager
Canadian Johns-Manville Co., Ltd.,
565 Lakeshore Road, East
Mississauga L5G 1H9
Ontario

Michael F. P. Michalski
Supervisor,
Limnology and Toxicity
Ministry of the Environment
P.O. Box 213
Rexdale, Ont.

E. Munro
Co-ordinator Envir. Systems
St. Lawrence Cement Company
2391 Lakeshore Road West
Mississauga L5J 1K1
Ontario

Grant Mills
Director,
Water Resources Branch
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5

E. F. Muller
Scientist
Ministry of the Environment
880 Bay Street
Toronto, Ont.

W.M. Mitchell
Lands Supervisor
Ministry of Natural Resources
Maple, Ont.

John A. Myers
Manager, Chemicals
Du Pont of Canada Limited
Maitland Works
P.O. Box 660
Maitland KOE 1P0
Ontario

R. G. Mondoux
Marketing Manager
Eimco Div. Envirotech Canada
165 Cartwright Avenue
Toronto, Ont.

John J. Myslicki
Electrical Engineer
Crown Asset Disposal Corporation
219 Argyle Street
Ottawa, K2P 1B8
Ontario

David Morin
Supervisor, Physical Sciences
Beak Consultants Ltd.,
306 Rexdale Blvd.,
Toronto M9W 1R6
Ontario

G. B. Nelson
District Officer, Industrial Abatement
Ministry of the Environment
4th Floor, 880 Bay Street
Toronto, Ont.

J. D. Norman, Ph. D.,
President
Pollutech Pollution Advisory Services
Limited
1094 Speers Road
Oakville, Ont.

John P. Nunan
President
Hydrology Consultants Limited
1125 Dundas Street E
Mississauga, Ont.

Stephen Nutt
Project Engineer
Pollutech Pollution Advisory Services
Limited
1094 Speers Road
Oakville, Ont.

K. A. Oakley
Associate Director, International
Joint Commission
Great Lakes Regional Office
Windsor, Ont.

E. F. O'Keefe
Sr. Approvals Engineer
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5, Ont.

L. K. Oliver
Mining Engineer
The Adams Mine
P.O. Box 877
Kirkland Lake, Ont.

M. Otis
Manager - Filtration, Water Pollution
Carborundum Company
35 Oak Street
Weston, Ont.

R.R. Parker
Chemical Engineer
Reid Crowther & Partners Ltd.,
1492 Don Mills Road
Don Mills, Ont.

S. N. Paul
Supervisor
Process and Waste Water Division
Dearborn Chemical Co., Ltd.,
Mississauga, Ont.

J. Peake
Co-ordinator, Environmental Conservation
Sun Oil Company Limited
56 Wellesley Street W
Toronto M5S 2S4
Ontario

Robert Pearsell
Senior Environmental Officer
Ministry of the Environment
1500 Fisher Street
North Bay, Ont.

Ronald Pearson
Supervisor, Inspection & Environment
Campbell Soup Co., Ltd.,
St. Marys, Ont.

C. A. Perl
Environmental Engineer
Stelco
100 King Street W
Hamilton L8N 3T1
Ontario

Albert Perras
Chemist, Water Effluents Laboratory
Ministry of the Environment
Resources Road
Rexdale, Ont.

T. H. Peters
Agriculturist
Inco
Copper Cliff, Ont.

Vladan Petranovic
Process Engineer
Arthur G. McKee
205 Queen's Quay West
Toronto M5J 1A7
Ontario

Bob Phoenix
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5

E. C. Pinder
Manager, Environmental & Human
Resources Department
The Board of Trade of Metropolitan
Toronto
11 Adelaide Street W
Toronto M5H 1M8
Ontario

W. M. Pinkerton
Senior Sanitary Engineer
Marshall Macklin Monaghan Ltd.,
1480 Don Mills Road
Don Mills, Ont.

L. F. Pitura
Regional Director
Ministry of the Environment
1825 Arthur Street
Thunder Bay "F"
Ontario

G. N. Plant
Project Engineer
James F. MacLaren Ltd.,
20 Erb Street W
Waterloo, Ont.

Charles Planzer
Manager, Environmental Engineering
Dominion Textile Ltd.,
1980 Sherbrooke Street W
8th Floor
Montreal H3H 1E7
Quebec

Dr. E.G. Pleva
Professor - Dept. of Geography
University of Western Ontario
London, Ont.

Wm. R. Price
Councillor
Corporation of Arnprior
31 Gary Crescent
Arnprior, Ont.

R. H. Prosser
Clarifier Foreman
Domtar Fine Paper Limited
800 2nd Street W
Cornwall K6H 5S3
Ontario

R. Proudfoot
Manager, Environmental Control
Ford Motor Co.,
Engineering Division
3001 Miller Road
Dearborn, Ont.

P. F. Pullen
Chief Environmental Engineer
Rio Algom Mines Limited
120 Adelaide Street W
Toronto, Ont.

Gordon Rach
Approvals Engineer
Ministry of the Environment
135 St. Clair Avenue W
Toronto, Ont.

Mike Pratt
Production Manager
Industrial Grain Products
Box # 37
Thunder Bay "F"
Ontario

Ian Ramsay, P.Eng.,
Industrial Abatement Section Manager
Northwestern Region
Ministry of the Environment
1825 Arthur Street E
Thunder Bay P7E 5N7
Ontario

J. C. Ramshaw
Senior Facilities Engineer
Corning Glass Works of Canada Ltd.,
Box # 720
Bracebridge, Ont.

T. E. Rattray
Solid Waste Engineer
Environment Canada
Place Vincent Massey
Ottawa, Ont.

Ken Reeve
Plant Engineer
Canadian Johns-Manville Co., Ltd.,
West Hill, Ont.

John D. Reid
President
Napier-Reid Limited
1875 Leslie Street
Unit 23
Don Mills M3B 2M5
Ontario

R. Richardson
Process Engineer
Canadian Pittsburgh Industries Ltd.,
3730 Lakeshore Blvd. W
Toronto M8W 1P3
Ontario

T. Barry Rose
Sales Representative
Cyanamid of Canada Limited
Niagara Falls, Ont.

Byron Roberts
Formosa Spring Brewery
P.O. Box 159
Barrie, Ont.

George R. Robertson, P.Eng.,
Sanitation and Pollution Control Eng.,
City Engineer's Department
Corporation of City of London
P.O. Box 5035
London N6A 4L9
Ontario

Robert V. Robinson
Pollution Control Supervisor
City of Barrie
165 Ferndale Drive
Barrie, Ont.

J. I. Rolfe
Senior Process Engineer
Norton Company
8001 Daly Street
Niagara Falls, Ont.

Frank A. Rovers
Project Engineer
Hydrology Consultants Limited
Mississauga, Ont.

R. Russell
Sales Engineer
Simon-Carves of Canada Limited
2025 Sheppard Avenue East
Willowdale, Ont.

S. E. Salbach
Supervisor
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

Gwyn Samuel
Senior Environmental Officer
Environment Ontario
985 Adelaide Street South
London, Ont.

G. W. Schindel
Environmental Control Co-ordinator
Imperial Oil Enterprises
P.O. Box 3004
Sarnia, Ont.

J. W. Schmidt
A/Environmental Quality Coordinator
Environment Canada
Canada Centre for Inland Waters
P.O. Box 5050
Burlington L7R 4A6
Ontario

Robert J. Schurko
Chemical Engineer
Canadian Industries Ltd.,
P.O. Box 10
Montreal H2C 2R3
Quebec

A. L. Scott
Engineering Supervisor
Imperial Oil Enterprises Ltd.,
Engineering Division
P.O. Box 3015
Sarnia N7T 7N1
Ontario

G.T.G. Scott
President
Canadian-British Engineering
Consultants (1971) Limited
801 York Mills Road
Don Mills, Ont.

Robert C. Scott, P. Eng.,
Coordinator of Environmental Control
Spruce Falls Power & Paper
Box 100
Kapuskasing P5N 2Y2
Ontario

Milan Sedivy
Environmental Control Officer
Texas Gulf
B-2002 Timmins,
Ont.

K. Segsworth
Supervisor of Air Management
International Nickel Co. of Canada Ltd.,
Copper Cliff, Ont.

Dennis Semkiw
Canadian-British Engineering
Consultants
420 King Street
Port Colborne,
Ontario

L. Sharman
Technical Consultant
Environmental Technical Services
293 Kenilworth Avenue N
Hamilton, Ont.

John Shrives
Planner
Ontario Ministry of the Environment
4375 Chesswood Drive
Downsview, Ont.

Paul G. Shewchuk
Engineer
Environment - Alberta
10040 - 104 Street
Milner Building # 605
Edmonton T5J 0Z6
Alberta

Kim Shikaze
Chief
Environmental Control Division, EPS
Environment Canada
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

Stephen Shivas
Chemist
Barrie Tanning Limited
55 Bradford Street
Barrie, Ont.

Edward R. Shuster
Manager,
Technical Services & Market Development
Chem-Trol Pollution Services, Inc.,
1135 Balmer Road,
P.O. Box 200
Model City
New York 14107
U. S. A.

R. A. Simmons
District Manager
Alchem Limited
211 Lakeshore Road E
Oakville, Ont.

E. R. Simonen
Pollution Control Div. Engineer
Regional Niagara
P.O. Box 509
St. Catharines,
Ontario

J. R. Sinclair
Environmental Control
Abitibi Provincial Paper Ltd.,
Thorold L2V 3Z7
Ontario

Ivan A. Sirman
Project Engineer
Environment - Canada
135 St. Clair Avenue West
2nd Floor
Toronto, Ont.

Dr. R. W. Slater
Director, Ontario Region
Environmental Protection Service
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

Duncan K. Smith
Assistant Director
Department Applied Chemistry
Ontario Research Foundation
Sheridan Park
Ontario

Rod Smith
Manager, Eng. Services
Green Giant of Canada
500 Ouellette
Windsor, N9A 1B6
Ontario

Walter Smithies
Consultant
Ontario Economic Council
950 Yonge Street
Toronto 5, Ont.

R. E. Soper
Supervisor
M. M. Dillon Limited
P.O. Box 426
London N6A 4W7
Ontario

B. A. Steele
Glass Chemist
Consumer Glass Co., Ltd.,
777 Kipling Avenue
Toronto M8Z 5G6
Ontario

Ronald R. Steingart
Manager, Engineering
H. J. Heinz Co. of Canada Limited
Erie Street S
Leamington, Ont.

Don Stevanov
Sales
Wemco Envirotech
35 Taber Road
Rexdale, Ont.

W. David Stevens
Commissioner of Industries
Kingston Industrial Commission
City Hall
Kingston K7L 2Z3
Ontario

A. D. Stewart
Manager - Environment Control
The Algoma Steel Corporation Limited
Sault Ste. Marie,
Ontario

Robert Stiles
Environmental Officer
Ministry of the Environment
2378 Holly Lane
Ottawa, Ont.

Willis Stephenson
Chief Engineer
Toronto Abattoirs Limited
2 Tecumseth Street
Toronto M5V 2R5, Ont.

W. P. Suboch
Head, Forest & Food Unit
Pollution Control Section
Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ont.

V. Suffoletta
Assistant Utilities Engineer
Technical Services
The Steel Company of Canada Limited
Hamilton, Ont.

F. J. Sweeney
Senior Process Chemist
Shell Canada Limited
Oakville Refinery
Box # 308
Oakville, Ont.

H. Gladys Swope
Associate Editor
Industrial Waste Magazine
214N Allen Street
Madison
Wisconsin 53705, U.S.A.

C. N. Taylor
Technician
Power Plant Supply Company
Oakville, Ont.

Jeffrey Taylor
Senior Chemical Lab. Technician
Ministry of the Environment
Northwestern Regional Laboratory
411 Donald Street E
Thunder Bay 'F', Ont.

Bob Thomson
Fish & Wildlife Supervisor
Ministry of Natural Resources
14 N. Algoma Street
Thunder Bay,
Ontario

F. R. Thompson
Scientist
Ministry of the Environment
Microbiology Section
Laboratory Branch
Box 213
Rexdale, Ont.

Gordon E. Thompson, P. Eng.,
Environmental Engineer
W. L. Wardrop & Associates Ltd.,
300-77 Main Street
Winnipeg
Manitoba R3C 3H1

E. Elmer Todd
Carleton Pumping Service
North Gower
Ontario

Dr. G. H. Tomlinson II
Vice-President
Research & Environmental Technology
Domtar Limited
P.O. Box 7210
Montreal H3C 3M1
Quebec

J. R. Townsend
Manager, Sales & Engineering
Sharples Div - Pennwalt
365 Evans Avenue, Suite 302
Toronto M8Z 1K2
Ontario

Lex Trelford
Technical Sales Representative
Domtar Chemicals Ltd.,
Lime Division
46 Hollinger Road
P.O. Box 68, Station "O"
Toronto M4A 2M8

Dr. Robert Tremblay
Technical Specialist
Government Quebec
255 East Cramazie Boulevard
Montreal, Quebec

Carman L. Trenholm
Technical Supervisor
Alchem Limited
Burlington,
Ontario

F. Tricker
Plant Manager
Tricil Waste Management
P.O. Box 786
Corunna, Ont.

G. S. Trivett
Assistant Director, Central Region
Ministry of the Environment
4th Floor,
880 Bay Street
Toronto, Ont.

John R. Turner
Technical Service Representative
Allied Chemical Canada Limited
100 N. Queen Street
Toronto M8Z 5N3
Ontario

N. F. Uffen
Sales Manager
Diversey Environmental Products Limited
2645 Royal Windsor Drive
Mississauga, Ont.

Edward A. Ulrich, P. Eng.,
Product Manager, Filtration
Toronto Coppersmithing Co., Ltd.,
220 Midwest Road
Scarborough M1P 3A9
Ontario

V. Uzbališ
Product Manager
Dearborn Chemical Co., Ltd.,
Mississauga, Ont.

Lorne D. Vance
Supervisor
Borg-Warner Chemicals
Box # 10
Norman Road
Cobourg, Ont.

W. A. Vanderland
Vice-President & General Manager
Can Pac Waste Disposal Systems Ltd.,
1470 Don Mills Road
Don Mills, Ont.

Dr. P. Victor
Senior Economist
Environmental Approvals Branch
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5
Ontario

Alan A. Wainio
Biologist
Ministry of Natural Resources
Maple, Ont.

Frank Walkom
Corp. Town of Goderich
Goderich
Ontario

A. R. Wallace
Manager, Engineered Products
Pumps & Softeners Limited
680 Waterloo Street
London, Ont.

John E. Waller
Research Director
Dearborn Chemical Co., Ltd.,
3451 Erindale Stn. Road
Mississauga, Ont.

J. K. Walter
Special Projects Engineer
Kilborn Engineering Limited
36 Parklawn Road
Toronto, Ont.

C. H. Watson
President
Master Industrial & Engineered
Services Limited
249 Lake Avenue N
Hamilton L8H 7J1
Ontario

John M. Watson
Project Engineer
Shawinigan Engineering
620 Dorchester Blvd. West
Montreal, P.Q.

L. R. Webber
Professor
Land Resources Science
University of Guelph
Guelph, Ont.

Andrew Weir
Senior Environmental Officer
Ministry of the Environment
12 Fairview Road
Barrie, Ont.

L. Whistance-Smith
Biologist
Ministry of Natural Resources
Wildlife Branch
4th Floor
Whitney Block
Queen's Park
Toronto, Ont.

Dr. R. Whitehead
Principal Chemist
James F. MacLaren Limited
320 Adelaide Street South
London N5Z 3L2
Ontario

K. R. Wilk
Approvals Engineer
Ministry of the Environment
135 St. Clair Avenue W
Toronto M4V 1P5

David L. Wilkins
Vice-President,
Sales, Equipment & Process Division
Environmental Technical Services Inc.,
293 Kenilworth Avenue N
Hamilton, Ont.

A. W. Wilson, Ph.D.,
Development and Applications Manager
Pollutech Pollution Advisory Services Ltd.,
1094 Speers Road
Oakville, Ont.

Art Wilson, Jr.
Production Sales
Interflow Systems
Box 3004
Station 'C'
Hamilton, Ont.

John A. Wilson
Supervisor
Environmental Control Equipment
Rexnord (Canada) Limited
1181 Sheppard Avenue East
Willowdale, M2K 1C6
Ontario

D. E. Winkup, P.Eng.,
Manager, Dealership Construction
Project Engineering
Chrysler Canada Limited
2450 Chrysler Centre
Windsor, Ont.

Wayne Witbeck
Project Engineer
L. S. Love & Associates
158 Kennedy Road South
Brampton, Ont.

Colin P. Wobschall
Project Leader
International Nickel Co. of Canada Ltd.,
Iron Ore Recovery Plant
Copper Cliff, POM 1N0
Ontario

J. E. Worley
General Superintendent
The Algoma Steel Corporation Ltd.,
Algoma Ore Division
Wawa, P0S 1K0
Ontario

M. Yatabe
Engineer
Gore & Storrie Limited
1670 Bayview Avenue
Toronto M4G 3C2
Ontario

Donald C. Young
Engineer
Metro Toronto - Works Department
11th East Tower,
City Hall
Toronto, Ont.

Ralph O. Young
Technical Manager
Federated Genco Limited
834 Appleby Line
Burlington, Ont.

M. B. Zcoca
Engineer
Pollutech
1094 Speers Road
Oakville, Ont.

T. Zsenaty
Stone & Webster Canada Limited
60 Adelaide Street E
Toronto, Ont.

TD
897.5
.057
1974
Jep 2

21st Order of Waste Management
in Mexico & proceedings
76605